Positioning Arizona for the Next Big Technology Wave: Development and Investment Prospectus to Create a Sustainable Systems Industry in Arizona

March 2004

ARIZONA DEPARTMENT OF COMMERCE
Our Job is JOBS!

Prepared by
the Battelle Technology Partnership Practice
as part of the
Arizona Statewide Economic Study

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Prepared by:

Technology Partnership Practice
Battelle Memorial Institute
Cleveland, Ohio

Peer reviewed by the Arizona Department of Commerce Economic Research Advisory Committee:

Dan Anderson
Assistant Executive Director for Institutional Analysis
Arizona Board of Regents

Brian Cary
Principle Economist
Joint Legislative Budget Committee

Lisa Danka
Director, Commerce & Economic Development Commission
Arizona Department of Commerce

Kent Ennis
Economic Consultant
CH2M Hill

Wayne Fox
Director, Bureau of Business and Economic Research
Northern Arizona University

James B. Nelson
Economic Development Manager
Salt River Project

William P. Patton, Ph.D.
Director of Economic Development
Tucson Electric Power

Elliott D. Pollack
Elliott D. Pollack & Co.

Tom Rex
Research Manager, Center for Business Research
Arizona State University

Brad Steen
Chief Economist
Arizona Department of Transportation

Marshall J. Vest
Director, Economic and Business Research
Eller College of Business and Public Administration
University of Arizona

Don Wehbey
Economist
Research Administration
Arizona Department of Economic Security

Technical review by members of the Sustainable Systems Prospectus Steering Committee

This report was prepared for the Arizona Department of Commerce with funding from the Commerce and Economic Development Commission. It will be available on the Internet for an indefinite length of time at http://www.azcommerce.com/Economic/default.asp. Inquiries should be directed to the Office of Economic Information and Research, Arizona Department of Commerce, (602) 771-1100.

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To the Reader:

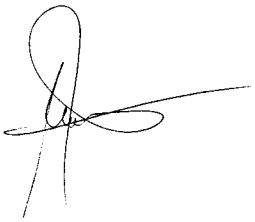
This Prospectus is part of a body of work known as the *Arizona Statewide Economic Study*, a decennial research project undertaken to provide the foundation for development of a 10-year economic strategy for Arizona. The *Arizona Statewide Economic Study* has been overseen by the Commerce and Economic Development Commission, the body responsible by state statute for developing the 10-year strategy.

Jointly commissioned by the Arizona Department of Commerce and the Arizona Board of Regents, the Sustainable Systems Prospectus follows an earlier report, "*Science and Technology Core Competencies Assessment*," that identified world-class research and development strengths in the state university system in the biosciences, advanced communications and information technology, and a broad group of ecological sciences that provide the innovation platform for sustainable systems.

In addition to the Prospectus, companion technology roadmaps resulting from the core competencies report include: Advanced Communications and Information Technology (ACIT), another joint effort of the Commerce Department and the Arizona Board of Regents (available mid April 2004 at http://www.azcommerce.com/Economic/default.asp); and the Biosciences Roadmap spearheaded by the Flinn Foundation (www.flinn.org). Collectively, the Sustainable Systems Prospectus and the ACIT and Bioscience roadmaps provide the focus and strategies needed to capitalize on Arizona universities research and development strengths in the creation of new products, new markets and high quality jobs.

Finally, we are grateful to the members of the Sustainable Systems Steering Committee - a team of experts from Arizona universities, the private sector and non-governmental organizations - who gave generously of their time and effort to ensure this Prospectus was balanced and economically justified. Their service was invaluable and on behalf of Governor Napolitano and the Arizona Board of Regents, I thank and commend them for their dedication.

Sincerely,



Gilbert Jimenez
Director, Arizona Department of Commerce
and
Chairman, Commerce and Economic Development Commission

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Sustainable Systems Prospectus Steering Committee

Co-chaired by: Wendy Vittori, Motorola Computer Group
Gilbert Jimenez, Arizona Department of Commerce

Members:
Todd Bankofier, Arizona Technology Council
Adriane Brown, Honeywell
Patrick Burkhart, Arizona State University
Rob Davis, Forest Energy, Inc.
Prabhu Dayal, C*Trade
Jonathan (Jon) Fink, Ph.D., Arizona State University
Carl Fox, Ph.D., Northern Arizona University
Hanafi Fraval, Aerrock, LLC
Andrew Gordon, Arizona MultiBank
Brian Hageman, Deluge
Bob Hagen, Southern Arizona Technology Council
Dick Hayslip, Salt River Project
Gail Howard, Office of the Governor
Stephanie Jacobson, Arizona Board of Regents
Saundra Johnson, Flinn Foundation
Peter Johnston, Arizona Public Service
Sheldon Jones, Arizona Agri-business Council
Mitra Khazai, Consultant
Kim Kristoff, GEMTEK, Inc.
Noah Kroloff, Office of the Governor
Andy Kruse, Southwest Wind Power
Stephanie McKinney, Greater Flagstaff Economic Council
Rob Melnick, Ph.D., Morrison Institute
Daniel Musgrove, Universal Entech, LLC
Stephen Owens, Arizona Department of Environmental Quality
Pat Patton, Ph.D., Tucson Electric Power
Dick Pieranunzi, ST Microelectronics, Inc.
Dick Powell, Ph.D., University of Arizona
Lucian Spataro, Jr., Ph.D., University of Arizona
Michael Strasser, Ponderosa Capital
Naranjan Vescio, Environmental Systems Products
Sandra Watson, Arizona Department of Commerce
Steve Weathers, Greater Tucson Economic Council
Rick Weddle, Greater Phoenix Economic Council
Bruce Wright, University of Arizona Office of Economic Development

FINAL REPORT

POSITIONING ARIZONA FOR THE NEXT BIG TECHNOLOGY WAVE:

DEVELOPMENT AND INVESTMENT PROSPECTUS TO CREATE A SUSTAINABLE SYSTEMS INDUSTRY IN ARIZONA

PREPARED FOR:
Arizona Commerce and Economic Development Commission and the Arizona Department of Commerce, in association with Arizona's Public Universities and the Arizona Board of Regents

PREPARED BY:
Technology Partnership Practice
Battelle Memorial Institute
Cleveland, Ohio

March 2004

Battelle
The Business *of* Innovation

Development and Investment Prospectus to Create a Sustainable Systems Industry in Arizona

PHASE II REPORT

PREPARED FOR:
ARIZONA COMMERCE AND ECONOMIC DEVELOPMENT COMMISSION
AND
THE ARIZONA DEPARTMENT OF COMMERCE,
IN ASSOCIATION WITH ARIZONA'S PUBLIC UNIVERSITIES
AND
THE ARIZONA BOARD OF REGENTS

Prepared by:
Technology Partnership Practice
Battelle Memorial Institute
Cleveland, Ohio

March 2004

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Abbreviations and Acronyms

AAGR	Average Annual Growth Rate
AHA	Arizona Hydrogen Association
APS	Arizona Public Service
ASSIA	Arizona Sustainable Systems Industry Association
ASU	Arizona State University
BECC	Border Environment Cooperation Commission
BPA	Bonneville Power Administration
CAP	Central Arizona Project
CASS	Central Arizona Salinity Study
CC&Rs	Covenants, Conditions, and Restrictions
CRADA	Cooperative Research and Development Agreement
DG	distributed generation
DHS	U.S. Department of Homeland Security
DM	deutsche mark
DOC	U.S. Department of Commerce
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
DSIRE	Database of State Initiatives for Renewable Energy
EDA	Economic Development Administration (DOC)
EE	energy efficiency
EERE	DOE's Office of Energy Efficiency and Renewable Energy
EIP	eco-industrial park
EPA	U.S. Environmental Protection Agency
EPS	Environmental Portfolio Standards
ERC	Engineering Research Center for Environmentally Benign Semiconductor Manufacturing
ES&H	environmental, safety, and health
ETIC	Environmental Technology Industry Cluster
EU	European Union
GCIT	Governor's Council on Innovation and Technology
GMO	genetically modified organism
IEN	indigenous environmental network
IP	intellectual property
IPC	integrated pollution control
IPP	independent power producers
ITEC	Inter-tribal Environmental Council
kW	kilowatt
kWh	kilowatt hour
LBNL	Lawrence Berkeley National Laboratory
LEED	Leadership in Energy and Environmental Design (U.S. Green Building Council)
MOU	Memorandum of Understanding
MRF	medium range forecasts
MTBE	methyl tertiary-butyl ether
MW	megawatt
NADB	North American Development Bank
NAU	Northern Arizona University

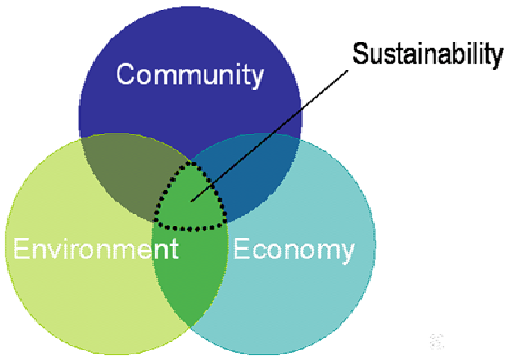
NGO	nongovernmental organizations
NIEHS	National Institute of Environmental Health Sciences
NIH	National Institutes of Health
NIWWTP	Nogales International Wastewater Treatment Plant
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
PNNL	Pacific Northwest National Laboratory
PV(s)	photovoltaic(s)
R&D	research and development
RBIP	Rural Business Investment Program
RD&D	research, development, and demonstration
ROI	return on investment
RPS	Renewable Portfolio Standard
RTI	Research Triangle Institute
RTP	Research Triangle Park
S^3T	Sustainable Systems Science and Technology Collaboratory
SABS	Saebi Alternative Building System
SAHRA	Center for Sustainability of semi-Arid Hydrology and Riparian Areas
SBA	Small Business Administration
SBIC	Small Business Investment Company
SEP	State Energy Program
SRP	Salt River Project
STAR	Solar Test and Research Center
SWEEP	Southwest Energy Efficiency Project
SWOT	strengths, weakness, opportunities, and threats
T+3M	Technology plus Money, Management, and Marketing
TEP	Tucson Electric Power
TRC	Tradable renewable credit
UA	University of Arizona
UC	University of California
UCS	Union of Concerned Scientists
USDA	U.S. Department of Agriculture
USFS	U.S. Forestry Service
USGS	U.S. Geological Survey
UV	ultraviolet
VNC	virtual network computing
WQIC	Water Quality Improvement Center
WRRC	Water Resources Research Center
ZDM	zero discharge manufacturing

Executive Summary

INTRODUCTION

More than 10 years ago the United Nations held a global conference in Rio de Janeiro that became known as the Earth Summit of 1992. Following many years of international debate regarding trade-offs between industrial development and problems of population growth and limited planetary resources, this watershed event resulted in a broad agenda for action in both the public and private sectors, based largely on the ***"sustainable development"*** concept: that is, development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Confronted with the sustainable development challenge, the business community is recognizing that long-term success depends not only on financial performance, but also on social and environmental performance. Since 1992, many chief executives of major companies such as DuPont, Intel, Motorola, Ford, and Johnson & Johnson have embraced "sustainability" as a business imperative.

Figure ES-1: The Triple Bottom Line



The Triple Bottom Line

A "sustainable enterprise" is a company that anticipates and meets the needs of present and future generations of customers and stakeholders, encompassing three dimensions known as the *"triple bottom line"* (Figure ES-1):

- Economic prosperity and continuity for the business and its stakeholders
- Social well-being and equity for both employees and affected communities
- Environmental protection and resource conservation, both local and global.

Sustainability includes a number of critical issues related to human and ecological welfare—climate change mitigation, pollution prevention, poverty reduction, and protection of human rights. Stakeholders in these issues include not only customers and shareholders, but also employees, local communities, regulators, lenders, suppliers, business partners, and advocacy groups.

An Emerging Market

The scientific challenges are complex and daunting—to clean up our environment, maintain our natural resource base, and reverse the effects of global warming, while at the same time ensuring economic growth and an acceptable quality of life worldwide. All the developed countries in the world have embarked on ambitious research, development, and deployment programs to address these issues. Many innovative technologies are being produced, which are fueling a growing global "sustainable systems" market, driven in large part by the increasing need for clean energy, clean water, and reduced industrial

pollution. For example, solar energy is now the world's second fastest growing energy source—at an average growth rate of 16 percent a year since 1990—and it is predicted to expand.[1] Global solar energy demand has grown at about 25 percent a year over the past 15 years, particularly in photovoltaic (PV) technologies.

Water is also turning into a booming business. Worldwide, annual industry revenues are estimated at $300 billion, with the United States accounting for more than half of that amount. This number is expected to grow as water becomes scarce and consumer markets begin to mature. Water markets are emerging in Australia, Chile, and Mexico, with expanding potential into the Middle East, Asia, and North and South Africa.[2]

Sustainable manufacturing is gradually entering the chemicals, automotive, and other traditional industries; but, to obtain a sense of where this area is heading, it is best to look at the semiconductor industry, because it is the most innovative industry in the world. The Semiconductor Industry Association reported that semiconductor sales increased 18 percent to $166.4 billion in 2003 and will rise approximately 19 percent in 2004.[3] Together with increased performance, this industry has been very aware of environmental, safety, and health issues and has mounted worldwide activities to move toward "green manufacturing." The World Semiconductor Council represents the majority of worldwide semiconductor manufacturing and has included environmental needs in the International Technology Roadmap for Semiconductors.[4] Working within this framework, the large global semiconductor companies such as IBM, Intel, ST Microelectronics, and Motorola have corporate level programs to make their products more environmentally friendly.

Intel and Green Design

Intel is committed to conserving natural resources and reducing the environmental burden of waste generation and emissions to the air, water, and land. Intel focuses on reducing the environmental footprint of its products, processes, and operations. Green design examples include

- Lead-free semiconductors and electronics
- Environmental performance and employee safety
- Energy conservation in PCs
- Scrap wafers to solar energy.

Arizona's Opportunity

Arizona is home to these and other companies that are committed to sustainability, as well as entrepreneurs and relevant university research core competencies that, collectively, could form the foundation for a broad-based sustainable systems industry creating high value jobs. The state also is a *"living laboratory"* for arid and semiarid lands, which represent more than a third of developable land in the world. Arizona has both large cities (Phoenix and Tucson) and small cities with easy access to rural communities (Flagstaff), and a highly diverse population. With these assets, Arizona should be able to produce a stream of knowledge, technologies, and products that address the triple bottom line. This Prospectus is intended to help position Arizona as a leader in this emerging area, providing products and services for the global market.

[1] "Solar Power Markets Boom," World Watch Institute, http://www.worldwatch.org/press/news/1998/07/16/.
[2] "The Rising Tide of Water Markets," ITT Industries, http://itt.com/waterbook/tide.asp.
[3] "Global Semiconductor Sales Up 18.3% in 2003," Semiconductor Industry Association, http://www.semichips.org/pre_release.cfm?ID=299.
[4] World Semiconductor Council, http://www.semiconductorcouncil.org/.

This Prospectus provides a framework for Arizona and its stakeholders, in both public and private sectors, to invest in creating an entire new industry, both products and services, supporting global sustainability. However, it is just a starting point for what will be a 10-year journey that will require a sustained partnership between governments, nongovernmental organizations (NGOs), universities, and industry. As investments are made and programs implemented, this Prospectus will need to be changed, modified, and updated. Finally, this Prospectus will need to be put into operation through a roadmap and annual operating plans.

Progress in Sustainability as This Prospectus Was Being Prepared

- U.S. Department of Agriculture broke ground on a new Arid-Land Agriculture Research Center in Maricopa in February 2004.
- Northern Arizona University (NAU) announced a new 100,000-square-foot building for the College of Business Administration that will be Leadership in Energy and Environmental Design (LEED) certified.
- Arizona Corporation Commission is considering advancing the portfolio standards for renewable energy.
- The Forest Health Task Force is developing a more holistic approach to forest health management and community protection for Arizona.
- The Essential Services Task Force is working on evaluating Arizona's gasoline and essential services and infrastructures, including electricity, natural gas, and water.
- Several communities such as Flagstaff and Prescott have developed economic growth plans that bring in sustainability and sustainable systems.

Project Methodology

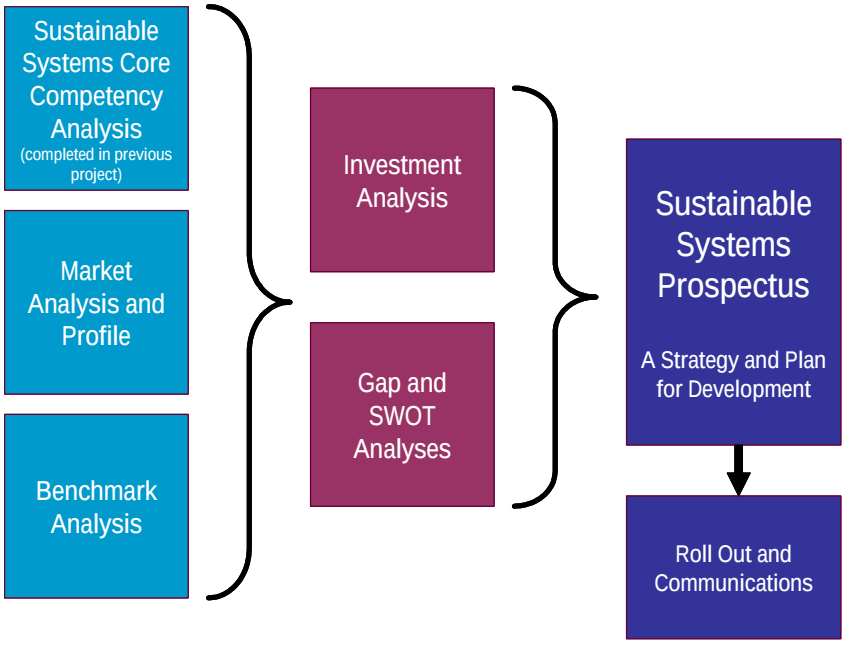
This project was conducted in two phases. In the first phase, Battelle's Technology Partnership Practice produced the *Science and Technology Core Competencies Assessment*, which was recently published.[5] Four important "technology platforms" that will best position Arizona to take greater advantage of its research universities for economic growth were identified: advanced communications, information technology, sustainable systems, and bioengineering.

In Phase II, Battelle was engaged to convert the opportunities inherent in the sustainable systems platform into a prospectus that would lay out a development path and investments needed to create a sustainable systems industry from the technology base.

As indicated in Figure ES-2, development of the Prospectus involved the following new activities:

[5] *Positioning Arizona and its Research Universities: Science and Technology Core Competencies Assessment*; prepared for Arizona Commerce and Economic Development Commission, April 2003.

Figure ES-2: Project Methodology Diagram



- Analysis of national and international market trends, developments, and opportunities on which to build Arizona's future within the segments of the "sustainable systems" industry;
- A benchmarking analysis of other states and regions that are considering elements of sustainable systems to learn best practices and other lessons;
- An infrastructure gap analysis, through intensive university, government, and industry interviews to determine strengths, weaknesses, opportunities, and threats (SWOT) facing these industries in Arizona and an assessment of needs on which to build;
- Development of a 10-year vision for Arizona in this competency area; and
- Development of a set of mutually reinforcing strategies and action plans, including resource needs, to further position Arizona in these industries.

Potential Areas of Sustainable Systems Focus/Market Potential

With an immature and diverse market such as "sustainable systems," there is, at least in the early stages, more *technology push* than *market pull* as customers are convinced to embrace new, potentially disruptive technologies/products. Therefore, the research base is critical to success in creating this market.

Arizona's Research Base

Arizona's three universities generate, in total, approximately $500 million per year of research and development (R&D) grants and contracts. From this combined base in

Phase I of this study, Battelle identified six core competencies that reflect areas of research focus in Arizona meeting the following criteria: breadth, depth, reputation, and impact on their field; competitive differentiation; ability to transcend single business areas; and hard for competitors to imitate. These are ecological sciences, agricultural and plant sciences, space sciences, computer modeling and simulation, electronics and optics, and chemistry and materials.

Arizona's strongest core competence by far is the ecological sciences. There are three areas of world-class research and scholarship in this broad and deep competence.

Arid/semiarid lands ecology—Battelle could not find another university system that possessed the same depth of knowledge.

Urban ecology—The Consortium for the Study of Rapidly Urbanizing Regions at Arizona State University (ASU) is a world leader, as indicated by the extension of the remote sensing and urban environmental systems studies to many other cities around the world.

Hydrology and water resources—The University of Arizona (UA) is first nationally in hydrology; add to that distinction the four water centers, each dealing with a different problem area, and ASU's and NAU's contributions, and Arizona has what is arguably the world's biggest and best water resource portfolio.

The field of plant sciences also has two strong research areas, which could be very powerful if integrated and linked to sustainable agriculture.

The **Plant Genomics Institute** at UA, led by Rod Wing, sequences plant genomes, which can be used in crop enhancement and as models for human disease.

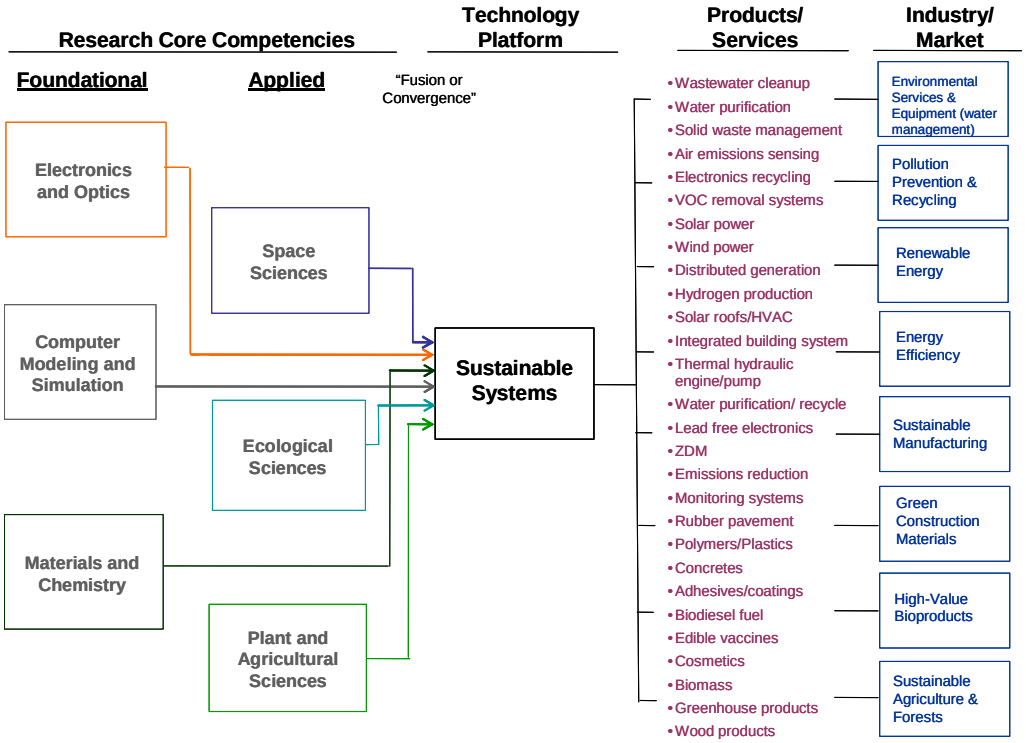
The **Arizona Biodesign Institute** at ASU, where Dr. Charles Arntzen's group is a world leader in development and manufacture of edible vaccines.

The remaining four core competencies support the current manufacturing clusters and will help further sustainable manufacturing in Arizona.

Sustainable Systems Technology Platform

Technology platforms serve as a bridge between the research core competencies and their use in commercial applications and products. The Sustainable Systems technology platform is the starting point for this Prospectus. As shown in Figure ES-3, it is a robust platform potentially providing many technology product opportunities that can serve several market segments.

Figure ES-3: The Map Linking Science and Technology with Products and Potential Markets



Arizona's Sustainable Systems Industry Base

Sustainable systems is an emerging market, which is impossible to characterize using traditional Standard Industrial Classification data. Therefore, in an alternative approach, the data in Table ES-1 were obtained from a combination of company interviews, the company's own designation, or Battelle's analysis. They represent, conservatively, the total number of such firms in Arizona.

Table ES-1: Firms and Employment Base for Sustainable Systems Market/Industry Segments

Potential Sustainable Systems	Total Companies	Total Employment
Environmental Services and Equipment	628	19,125
Pollution Prevention and Recycling	106	1,223
Renewable Energy	83	818
Energy Efficiency	54	1,462
Green Construction Materials	9	172
High-Value Bioproducts	7	205
Sustainable Agriculture and Forests	47	1,161
Total Count	**934**	**24,166**

As a conservative estimate, more than 900 companies provide sustainable systems products/services, with an employment base of approximately 24,000 in Arizona. Most of

these are small businesses, employing fewer than 30 people. Not surprisingly, environmental services and equipment is the largest subsector, followed by a combined renewable energy and energy-efficiency group.

Despite its small size, this is a good foundation on which to grow an industry. By way of comparison, 10 years ago, in 1993, the employment base for the semiconductor industry in Arizona was only about 25,000; but, today it is a major industry cluster.[6]

Potential for Growth

Interest is growing in sustainable systems in Arizona, despite the fact that the industry base is relatively small. Most sustainable systems segments showed significant activity by companies, entrepreneurs, or other advocates, producing a level of innovation that indicates potential growth over the time period of this Prospectus. Tables ES-2 to ES-7 summarize some of the key developments, obtained from reports, Web sites, and extensive interviews with experts from all sectors in Arizona.

Table ES-2: Key Developments in Energy Efficiency and Renewable Energy

Industry Segment	Key Developments
Energy Efficiency	• The **Southwest Energy Efficiency Project (SWEEP)** study concludes that the potential for energy-efficiency improvements in Arizona is tremendous and represents replacement of 12 500MW new power plants. Also, 24,100 new jobs can be created by 2020 in the industries supporting energy efficiency. • Of the 34,000 **Energy Star homes** built nationally in 2001, more than 8,000 were built in Arizona, leading the United States. • Arizona homebuilders, supported by programs from **APS and TEP**, are national leaders in offering guaranteed heating and cooling costs. • All major cities have "green" building standards. • Communities such as Civano, campuses such as NAU, and commercial buildings in Phoenix are all pursuing **LEED** designations. • A new solar energy firm, **So Cool Energy Inc.,** is financing new solar heating/cooling systems in commercial buildings and schools. • **Deluge, Inc**., has developed the Thermal Hydraulic Engine, the first engine to be powered only by hot water supplied by geothermal, waste heat, or solar sources.
Renewable Energy	• **Environmental Portfolio Standard** requirements are driving the three major utilities (APS, TEP, SRP) to install solar power plants at a fast pace. Most MW generation in the United States. • **Fourteen new renewable energy projects** committed through 2002—solar, wind, and biomass. TEP long-term goal is 20% solar power by 2020. • **www.AzSolarCenter.com** is getting more than 20,000 discrete hits per month, and this rate is rising almost exponentially. • **APS Solar Test and Research Center (STAR)** provides the research needs of both APS and solar equipment manufacturers. STAR is the only facility of its kind in the United States. **ASU-East** has one of the three fully accredited PV test labs in the United States. • **Solargenix** has committed financing to deploy its solar thermal technology with Arizona utilities. • **C TRADE** is a new company formed to develop Carbon Trade Credits for renewable energy projects. • **American Hydrogen Association** is active in Arizona. Goal of AHA is to stimulate interest and help establish the renewable hydrogen energy economy by the year 2010.

[6] *Arizona Advanced Communications and Information Technology Roadmap,* prepared by Battelle for Arizona Commerce and Economic Development Commission, March 2004.

Table ES- 3: Key Developments in Environmental Services and Equipment (water management)

Industry Segment	Key Developments
Environmental Services and Equipment (water management)	• **Scottsdale Water Campus** is currently the largest facility in the nation to treat wastewater to drinking water standards using microfiltration and reverse osmosis technologies, setting high standards for the state. • Both **UA** and **ASU** have R&D underway to advance water management approaches for arid/semiarid regions, e.g., DEWVAPORATION. • **CIW Services** is a fast-growing local company with full engineering, manufacturing, and service capabilities, providing high-quality water treatment products and services. • **Zeta Corporation** developed the Zeta Rod, the first application of electronic treatment technology into high-volume flows of industrial cooling water and other processes.

Table ES-4: Key Developments in Sustainable Manufacturing and Pollution Prevention and Recycling

Industry Segment	Key Developments
Sustainable Manufacturing	• Large global semiconductor companies in Arizona, such as **IBM, Intel, ST Microelectronics, and Motorola** have corporate-level programs that address workplace environment, safety, and health issues and making their products more environmentally friendly. • **Intel, IBM, ST Microelectronics,** and others clean their process water for recharge into the aquifer or reuse in other parts of their sites. • Ultrapure water and water conservation are two major research topics at the **UA's Engineering Center for Environmentally Benign Semiconductor Manufacturing**. • **Gore** has introduced energy-efficient systems and water conservation into all its plants, including Flagstaff.
Pollution Prevention and Recycling	• The **Arizona Partnership for Pollution Prevention** provides a networking and mutual help system for companies to promote hazardous waste reduction. • **Universal Entech** designs, builds, and operates integrated solid waste management systems, including transfer stations, MRFs, IPCs, and composting. • **Pantheon Chemicals** provides environmentally safe, cost-efficient cleaning, lubricating, and pre-painting solutions as viable alternatives to existing hazardous or toxic solvents and cleaners. • **Innovative Formulations Inc**. develops innovative products that are both human and ecologically friendly.

Table ES-5: Key Developments in Green Construction Materials and High-Value Bioproducts

Industry Segment	Key Developments
Green Construction Materials	• Several small firms are producing "green materials" for different applications, and industry associations are promoting green products (e.g., **AerRock, ELF, Polypore, Rastra, Polylink**). • **Strata International Group** has developed a sustainable composite building technology based on polystyrene coated on both sides with fiber-reinforced concrete. • **Rubber Pavement Association**, Tempe, represents the rubber/asphalt industry, with 30 members worldwide and four in the Phoenix area. There are two companies in Phoenix building crumb rubber producing plants. Several projects are underway with ASU.
High Value Bioproducts	• **GEMTEK Products** is the only bioproduct manufacturer in the state. It produces biobased cleaners, solvents, lubricants, personal care and other specialties, and alternative fuels from soy, canola, corn, and peanuts. • **Integrated Energy Technologies** is interested in salt-tolerant plants such as sea asparagus, which is a potential source of oil as well as food. The Colorado River Delta is a potential demonstration site. • **University research** is focused on edible vaccines (ASU), cancer drugs (UA), and nutritional products (UA). Innovative discoveries are being made.

Table ES-6: Key Developments in Sustainable Agriculture

Industry Segment	Key Developments
Sustainable Agriculture	• **Cotton industry** strategy to capture high-end, high-value market for quality, with a new seed breeding program to increase both yields and quality that will demand premium prices. • About 85 percent of the country's leafy green vegetables are grown in the Salinas Valley in summer and Yuma in the winter, providing a year-round business for **Dole** and others. Farmers served by SRP are in a better position than California farmers (Imperial Valley) served by the Colorado River, who now face water curtailments. • Arizona has three areas falling in the top three greenhouse sites in the world, and is home to two major companies, **Eurofresh and Heinz**, involved in growing high-value fruit, vegetables, and flowers in greenhouses using hydroponics.

Table ES-7: Key Developments in Sustainable Forest Products

Industry Segment	Key Developments
Sustainable Forest Products	• The **Governor's Forest Health Oversight Council** is developing policy based on sound science. • **Greater Flagstaff Forests Partnership** is an alliance of 25 academic, environmental, business, and governmental organizations in Flagstaff, dedicated to testing and adapting new approaches to restoring forest ecosystem health in the forests surrounding Flagstaff. • **A forest-based renewable industry** is gaining momentum, and investors and entrepreneurs are proposing new secondary wood products companies based on emerging technologies. • **Forest Energy Corporation** produces natural wood pellets and densified logs for building heating/hot water systems, which is far more efficient than electricity production from biomass.

Sustainable Systems Market Trends

National Markets. In terms of markets relating to sustainable systems, a major environmental industry has emerged over the past 20 to 30 years in the United States. A comprehensive study by the U.S. Department of Commerce placed the size of the environmental industry by the late 1990s at $181 billion, with more than 110,000 companies employing more than 1.3 million Americans and more than $16 billion in exports. This translates into the environmental industry being larger than paper and allied products, petroleum refining, and aerospace, and nearly as large as motor vehicles.

By the late 1990s, however, growth of the environmental industry had leveled as environmental regulations that created much of the market growth in the 1980s and early 1990s stabilized and no longer drove growth. Therefore, more recent market forecasts suggest continued mixed, but generally positive performance. Table ES-8 describes trends along the market segment lines that Battelle has selected, based on data from various sources, including Environmental Business International,[7] Business Communications Company,[8] and Clean Edge.[9]

[7] Environmental Business International, http://www.ebiusa.com/.
[8] Business Communications Company, http://www.buscom.com/.
[9] Clean Edge, http://www.cleanedge.com/.

This entire market area may well receive new impetus nationally as a result of the "new Apollo Project" just launched by a coalition of labor unions, environmentalists, and congressional Democrats. The plan calls for a $300 billion federal investment over the next 10 years in clean energy technology such as "green buildings," more energy-efficient appliances, renewable energy sources, and modernized manufacturing and electricity infrastructure. The return on this investment is estimated at $1.4 billion in new gross domestic product and the creation of 3.3 million jobs, as well as a net energy cost savings of $284 billion.[10]

Table ES-8: Summary of National Market Trends in Sustainable Systems

Market Segment	Trends
Environmental Services and Equipment (water management)	• Solid waste management services grew by 3.6% from 2000 to 2001. • Hazardous waste management services grew by 3.0% from 2000 to 2001, but expected to fall in revenues from $2.35 billion to $2.32 billion by 2007. Top three firms account for more than 45% of the market. • Site remediation—4.0% AAGR. • Advanced wastewater treatments—5.5% AAGR from $3.5 billion in 2001 to $4.6 billion in 2006. United States is fastest growing sector with 1/3 of market. Asia and Europe each have 20%. • Advanced municipal water treatment technologies (e.g., membrane filtration, ozone disinfection, UV irradiation, etc.)—23.1% AAGR. • Air monitoring equipment and sensors—9.8% AAGR. • Biotechnology for environmental management—8.3% AAGR; $103.5 million in 2001 and expected to record annual growth of 8.3%, reaching $154 million by 2006. • Emission control products will grow by 5.4% annually. • Market for filters will grow by 4.7% annually.
Pollution Prevention and Recycling	• Process and prevention technologies grew by 6% from 2000 to 2001. • Resource recovery market grew by 2.0% from 2000 to 2001.
Renewable Energy	• Market size for U.S. alternative power generation was 368 billion kilowatt hours in 2001, up 1.0% from 2000 and 6.7% from 1997. • California predicts that Renewable Portfolio Standard of 20% would create about 119,000 person-years of employment by 2010, most in geothermal and wind industries. • Global solar PV market continues its strong growth, at a rate of about 20% annually. • Ethanol production should increase by 15% annually as it replaces MTBE. • Wind power will expand by 79% annually and represent about 6% of the nation's electrical power by 2020.
Energy Efficiency	• U.S. savings per household (1997) were $530. • Since the 1980s, EE programs in Massachusetts saved $4 billion, created more than 20,000 new jobs in EE industry, created fewer blackouts and cleaner air, and had an estimated ROI of 2:1. • In San Jose, California, annual energy savings today are $4.5 million. • U.S. industrial sector energy savings projected to be 32.6% by 2020. • U.S. commercial sector energy savings projected to be 37.3% by 2020. • A number of national organizations and programs also encourage green buildings (e.g., LEED), and growth is expected to be 3% annual average.

[10] New Technology Week, January 20, 2004.

Table ES-8: Summary of National Market Trends in Sustainable Systems (continued)

Market Segment	Trends
Sustainable Manufacturing	No specific data, but the trend in the semiconductor industry is being reflected in traditional metals and chemicals industries, the automotive industry, and the biotechnology industry. Therefore, Battelle anticipates continued growth of sustainable manufacturing and the enabling systems such as water, energy, and toxic material management.
Green Construction Materials	• Demand for plastic and wood-plastic composite material will grow by 13% annually. • U.S. Green Building Council forecasts an increasing trend in green building—up 3% in 2003. • Use of concrete for residential housing has grown from 8 percent to 14.4 percent in past 4 years.
High-Value Bioproducts	• Green solvents—6.0% AAGR. • U.S. market for plant-derived chemicals will grow by 6.8% annually.
Sustainable Agriculture	• Market for organic foods has increased approximately 20% per year.
Sustainable Forest Products	• Low prices for wood products have depressed this market, although the new housing construction sector is growing. Demand for paperboard and panels remains relatively soft. Duties and quotas have been applied to softwood imports from Canada, Russia, etc.

Global Markets. The global markets for sustainable products in the energy and water sectors are more mature in other countries than the United States. Japan, Canada, and the European Union (EU) countries are considered global leaders in sustainable development and have shaped their policies so as to take the lead in transitioning to sustainable systems. Three sectors exhibit high growth potential.

Renewable Energy. Solar energy is now the world's second fastest growing energy source—at an average growth rate of 16 percent a year since 1990—and it is predicted to expand.[11] Global solar energy demand has grown at about 25 percent a year over the past 15 years, particularly in PV technologies. The solar PV industry now globally generates between $3 million and $4 billion in revenues and will continue to expand. Of the global demand for solar PVs, more than 35 percent is accounted for by Japan, 25 percent by European countries, and less than 15 percent by the United States. In 1999 alone, the global solar market for PV systems reached $1 billion.[12] PVs are now being used in most of the industrialized countries and in more than 175,000 villages worldwide, producing thousands of jobs and creating economic opportunities in more than 140 countries.[13] Major energy companies such as Shell, BP, and Enron endorsed solar energy by investing heavily in PVs in recent years and are planning significant increases in the solar industry.[14]

[11] "Solar Power Markets Boom," World Watch Institute, http://www.worldwatch.org/press/news/1998/07/16/.
[12] "Global Solar Markets May Grow Ten-Fold by 2010," Environmental Expert News, http://www.environmental-expert.com/news/sep8-14/news3.htm.
[13] "Solar: Jobs for Today and Tomorrow," Solar Energy Industry Jobs, http://www.solardev.com/SEIA-solarjobs.php.
[14] "The BP gasoline station with PV panels on the roof," Energy Saving Now! http://energy.saving.nu/energytoday/renewable.shtml.

Currently, Japan, the United States, and Germany constitute 71 percent of the world market for solar PVs. In Germany and Japan, grid-connected applications accounted for more than 95 percent of the world market. Gesellschaft fur Solarenergie (GEOSOL) and Shell Solar have just announced that they will team to build what the companies said will be the largest solar power station in the world: a 5MW power station south of Leipzig, Germany.[15] Germany has now overtaken the United States as the largest net exporter of PV cells and modules, mostly for residential roof-mounted systems and building integrated PVs. It also is the largest market in Europe for PVs, with market share of 56 percent in 2000.[16] Japan is now the country with the most PVs installed per person.[17] In 2002 alone, the Japanese solar roof program received applications from 42,838 households.[18] Dynamic solar markets also have been developed in Greece, Austria, Spain, France, Switzerland, Denmark, and Australia.

While thermal solar energy is still at the developmental state, the potential demand for thermal solar systems is significant. Markets for thermal solar energy are emerging in northern and southern Africa, western Australia, Asia, and the Middle East. The United States currently leads the thermal solar industry, but Japan and the EU are becoming America's strongest competitors.

Continuous production improvements, falling prices, and global environmental concerns are opening up new markets for PVs and thermal technologies, giving the countries that own solar technologies tremendous business opportunities. The prospects for both PV and solar thermal sectors look very good for the coming years. The global market for solar electric technology will continue to expand and is predicted to grow to $10 billion by 2010. While the focus is mostly on European countries, the United States, and Japan, high growth rates for solar technologies are projected in developing countries coping with poor utility grid systems and lacking their own solar technologies.

Energy Efficiency. The global market for energy-efficient technologies is emerging in both the industrialized and developing world. It is estimated that, in 1999, the global market for energy-efficient goods and services reached $105 billion.[19] The energy-efficiency markets are primarily found in the United States and western Europe. However, demand for energy-efficient products is appearing in Latin America, Asia, eastern Europe, and Africa. Developing countries, in general, are experiencing an increase in energy demand due to population and economic growth, but face capital constraints in meeting these energy needs. Energy efficiency is perceived to become a crucial means to help meet rising energy demands. Developing countries will require investments of more than $100 billion to meet their energy needs. Only $12 billion of external funding is presently available, leaving a tremendous potential for energy-efficiency products to make up for the lack of domestic funds.[20] Most of the capital requirements will be needed in Asia and countries of the Former Soviet Union. This also

[15] New Technology Week, January 26, 2004.
[16] "PV in Europe," *REFOCUS*, May/June 2003, p. 48.
[17] "Photovoltaic Industry Statistics: Countries," Solarbuzz 2003, http://www.solarbuzz.com/StatsCountries.htm.
[18] "Solar Energy Global," Solarbuzz, 2003, http://www.solarbuzz.com/FastFactsIndustry.htm.
[19] "Global Markets for Energy-Efficient Products…," http://www.bccresearch.com/editors/RDEC97.html.
[20] UNIDO, https://www.unido.org/userfiles/PloutakM/7.

means major business opportunities for energy-efficiency companies and a chance to reduce greenhouse gas emissions as those countries pursue rapid modernization.

Water Management. As water supply and quality is becoming a global problem, water also is turning into a booming business. Worldwide, annual industry revenues are estimated at $300 billion, with the United States accounting for more than half of that amount. This number is expected to grow as water becomes scarce and consumer markets begin to mature. Water markets are emerging in Australia, Chile, and Mexico, with expanding potential into the Middle East, Asia, and North and South Africa. Some of the largest global water companies, such as Azurix, Suez Lyonnaise des Eaux, and Vivendi, have expanded their business to emerging water markets. The French water giant, Vivendi, now operates in numerous countries around the world, making annual revenues of more than $16 billion.[21]

Water scarcity and poor water quality have led to the rising need for transport infrastructure, wastewater treatment, and water efficiency technologies. Water and wastewater treatment demand, for example, is currently at $122 billion, constituting 40 percent of the world environmental market. The market volume for irrigation is at about $30 billion a year. Demand for micro-irrigation and low-pressure sprinkler technologies is growing at about 10 percent and will grow even more with a rising focus on water efficiency. Desalination of seawater and wastewater is experiencing 20 percent growth. Desalination is particularly sought by the southern countries where water is scarce. Currently, 13,000 desalination plants operate in 120 countries. The market, currently worth approximately $2 billion, is forecast to grow to $70 billion by 2020. Water treatment and disinfection technologies grow at about 10 to 15 percent each year, with a market value of about $5 billion a year each.[22]

BENCHMARKING ANALYSIS

A benchmarking review of leading and competitor regions was undertaken to identify, analyze, and draw useful lessons from the practices of regions and institutions that are generally comparable along certain relevant strategic dimensions. Specifically, Battelle was looking to

- Identify the competition
- Learn where the state stands
- Isolate the strategic issues
- Find out what works.

Benchmark Selection Criteria

- Obvious competitors
- Commitment to sustainability
- Home to relevant industry sectors
- Federal labs or other federally funded initiatives
- University Centers of Excellence

Based on selection criteria, Battelle settled on six domestic and two international benchmarks: California, Colorado, New Mexico, North Carolina, Oregon, Washington, the European Union, and Vancouver, BC (Canada).

[21] "The Rising Tide of Water Markets," ITT Industries, http://itt.com/waterbook/tide.asp.
[22] Sustainable Asset Management, "Investment Opportunities in the Water Sector," 2001 report.

Summary of Lessons Learned

Each of the benchmarks is a viable competitor in sustainable sectors, and several have explicit economic development goals.

Each of the six benchmark U.S. states and two international regions has displayed an impressive commitment to sustainability as a fundamental ethic of government and private-sector operations (Table ES-9). Each effort has been driven by different political forces and emphasizes different thrusts, including energy, water, pollution prevention, and "green manufacturing." What distinguishes several of the benchmarks is a commitment to make developing sustainable industries a cornerstone of an economic development strategy.

Table ES-9: State and Regional Sustainable Development Competition

State/Region	Apparent Thrusts/Interests in Sustainable Sectors	Driven by	Economic Component of Sustainability Policy	Status of Industry Sector
California	Air quality; power reliability; green buildings	State government bureaucracy over several Governors; grass-roots	Implicit strategy to make an economic virtue of regulatory necessity by levering the size of the market	Achieving high national profile
Colorado	Solar; green buildings	Grass-roots; "small is beautiful" constituency; builders	Not yet in place	Industry dominated by retail and grass-roots advocacy
New Mexico	Solar; green manufacturing	Governor and Congressional delegation	Explicit commitment to economic growth	Industry sector still nascent
North Carolina	Green manufacturing; farm-waste reuse; forestry	Last two Governors and the public university system	So far only in the sense of service to existing industry and agriculture, and efficient use of public resources	Strong environmental services sector; others lagging
Oregon	Clean power; watershed management; climate stewardship	Governor and grass-roots	Explicit commitment to triple bottom line	Portland emerging as a center of sustainable industry trade
Washington	Clean power; power reliability; forestry/bioproducts	Governor and grass-roots (local public utilities)	Explicit commitment to triple bottom line	Northwest/BC emerging as a center of fuel cell development
EU	Sustainable transportation, industrial ecology, environmental management systems	Top-down EU R&D programs, and bottom-up industry networks and NGOs	Explicit component of all R&D programs in Sixth Framework	Industry networks for material re-use and trading
Vancouver, BC	Urban sustainability	Provincial and regional environmental programs	Environmental industries recognized as key economic driver	Fuel cells development influencing NW "hydrogen corridor"

Simply having a state energy office that investigates renewable sectors does not distinguish the benchmarks.

Energy production and energy efficiency dominate the states' "sustainability" plans. Reviewing the activities of the State Energy Program (SEP) offices, it is apparent that each (including Arizona's) has conducted innovative feasibility studies and pilot deployment projects in many of the 11 program areas and nine industrial sectors supported by the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE).[23] (California does have an outsized commitment to the vehicular/fuel program areas.) Most of the principal partnering activities sponsored by EERE show relatively little variation across the benchmark set (Table ES-10).

Table ES-10: Energy Programs

State/Region	Million Solar Roof Non-State Partners	Clean City Coalitions	DOE Allied Partners in-State	Industry of the Future Partnerships	$ FY03 Special Projects to SEP Agency	FY01–02 Total $ to State from BTS (millions)	2002 Population (millions)
Arizona	3	2	1	4	$689,756	$3.6	5.5
California	13	12	7	2	$3,474,630	$47.7	35.1
Colorado	5	3	5	5	$430,632	$46.4	4.5
New Mexico	1	1	0	3	$577,790	$4.2	1.9
North Carolina	2	1	7	4	$574,996	$10.3	8.3
Oregon	0	2	5	6	$208,722	$6.2	3.5
Washington	2	1	5	3	$774,468	$25.1	6
EU	Not applicable						
Vancouver, BC	Not applicable						

Sources: Million roofs: http://www.millionsolarroofs.org/partnerships_statelocal/.
Clean Cities: http://www.ccities.doe.gov/coalitions_map.shtml.
Allied partners: http://www.oit.doe.gov/bestpractices/partners.cfm.

None of the benchmarks has yet fully aligned its energy programming with economic development, but several are on the cusp.

One of the benchmarks, California, has gone well beyond minimal federal requirements for the SEP and added substantial budgetary authority for conducting R&D (not just deployment) of alternative energy technology. Oregon has given itself the capacity through a public-benefit fund to address the same goals, but so far the fund is supporting deployment and not R&D. North Carolina, New Mexico, and Washington State have all

[23] The 11 program areas are biomass; building technologies (which administers the state partnerships programs); distributed energy and electric reliability; federal energy management; vehicular technologies; geothermal technologies; hydrogen, fuel cells, and infrastructure; industrial technologies (administers the OIT program); solar technologies, weatherization; and wind/hydropower. The nine industry sectors are agriculture, aluminum, chemicals, forest products, glass, metalcasting, mining, petroleum, and steel.

supplemented the activities of their SEP offices with the industrial extension and outreach functions of their state university systems; and in Washington, energy technology is being added as a sector targeted by the technology partnership agency. None of the benchmark states has put all the elements together, but it seems likely that one or more shortly will (Table ES-11). For instance, Governor Richardson of New Mexico recently announced, in his State of the State address, a bold new plan to construct a large commercial solar power plant by 2006, and major water projects, all tied to economic development and job growth.[24]

Table ES-11: Energy Benchmarks

State/Region	Additions to Basic State Energy Program	Role of State Agency for Tech-Based Development	Comment
California	$62 million energy R&D program (public-benefit funded) Air quality and pollution prevention programs with their own R&D budgets	Minimal. Some attention to environmental services cluster in San Diego	Purchasing power of California Power Authority used to nurture alternative power companies
Colorado	None	No lead agency for tech-based development. Governor now focusing on IT and bioscience clusters	Advocacy community is pushing a public-benefit fund
New Mexico	State-funded, university-managed environmental research consortium handles pollution-prevention leadership	Agency has minimal programming. Most efforts at regional (Albuquerque) level	Gubernatorial interest likely to redirect cluster initiatives
North Carolina	Department of Administration stewards the state government and university system pollution-prevention initiatives Sustainability one key thrust of NC State Industrial Extension Service and outreach programming	Expansion of state-funded biotech center to embrace forest biotechnology Funding available for sustainable crop development and waste management through tobacco settlement board	Environmental services sector has long been a recruiting target based on R&D strengths at universities, RTI, and federal labs. May be connections with existing ag-biotech cluster
Oregon	Permanent sustainability board Energy Trust (public benefit fund, but no R&D component) Climate Trust Clean Diesel initiative in pollution prevention agency	No lead agency for tech-based development	Likely that governor's new thrust may place stronger emphasis on company formation
Washington	Strong involvement of WSU cooperative extension in SEP functions Bonneville Electric Foundation as a substitute for a public-benefit fund	Addition of energy technology to mandate of Washington Technology Center Continued emphasis on precision forestry and agriculture in state-supported programs at UW and WSU	
EU	N/A	N/A	Explicit component of Sixth Framework R&D program
Vancouver, BC	N/A	N/A	

[24] http://www.governor.state.nm.us/pdf/stateofstate2004.pdf.

The benchmarks are differentiated by how they are using federal facilities—including those in other states.

In addition to presence of an R&D fund, one of the factors that distinguishes the benchmarks from each other is the presence of federal laboratories with capacity in sustainable systems and the resources to participate in partnership activities that are funded either through the laboratory itself or by headquarters operations in Washington, DC (Table ES-12).

Table ES-12: Targeted Federal Funding

State	Major Federal Facilities Levered	How	Comment
California	UC-managed labs (esp. LBNL, Los Alamos)	The labs feed UC research networks on energy and environment	Not a major component of California strategy to date
Colorado	NREL	Underutilized to date; mainly collaborations with School of Mines	State has not yet learned to effectively leverage the lab or its commercialization function
New Mexico	Sandia and Los Alamos	Extensive commercialization and industrial service commitments by both lab managers (Lockheed-Martin and UC)	To date the labs have been worked for other clusters (optics, microsystems), but sustainable sectors are sure to follow, starting with PV and solid-state lighting
North Carolina	NIEHS and EPA labs in RTP	RTP has been marketed to environmental service firms	Federally supported NC Solar Center, though not a federal lab, has boosted state's visibility
Oregon	EPA and Forest Service Labs at Oregon State University. BPA	Extensive university–agency research collaborations, including joint use of facilities and staff	An MOU between Oregon University System, Oregon Health and Sciences University, and PNNL has produced several joint programs, including the state's first ***Signature Research Center for Multiscale Materials and Devices,*** which will revolutionize energy and chemical systems
Washington	PNNL BPA	PNNL organizes a bioproducts consortium, and BPA helps fund renewables deployment	PNNL supports a significant environmental services cluster in Tri-Cities and throughout the state, and is a major contributor to state hydrogen and fuel cell initiatives
EU	N/A		
Vancouver, BC	N/A		

Traditional benchmarks show California as the clear leader.

California is the only one of the six benchmark U.S. states to meet all four criteria articulated by the Union of Concerned Scientists (UCS) for development of a renewable energy sector—and it also is one of three in the set to have at least one formal program

targeted at industrial recruitment in the sustainable sectors, as tracked by the Database of State Incentives for Renewable Energy (DSIRE) (Table ES-13). As a consequence, California leads the benchmarks in most UCS award categories, with a distant second-place performance in new renewables by both Oregon and Washington, whose efforts are grass-roots dominated (Table ES-14). Finally, data published by the Green Building Council show California again a dominant leader in LEED projects, followed by Washington and Oregon (Table ES-15).

Table ES-13: California, the Benchmark Leader

State	Renewable Standards (UCS)	Public Benefit Fund (UCS)	Net Metering (UCS)	Disclosure (UCS)	Recruitment Incentives (DSIRE)
Arizona	X	X	X	X	
California	X	X	X	X	X
Colorado			X	X	
New Mexico	X	X	X		
North Carolina					X
Oregon		X	X	X	
Washington			X	X	X
EU	N/A				
Vancouver, BC	N/A				

Source: UCS categories: http://www.ucusa.org/energy.
DSIRE: http://www.dsireusa.org/summarytables/.

Table ES-14: Benchmarks in UCS Award Categories

Category	Benchmarks in Winning Set
Most total funding for renewables	California
Highest Annual Average Funding per Kilowatt-Hour over Life of Fund	California
Disclosure required outside comprehensive restructuring	Colorado
Most new renewables installed	California, Washington, Oregon
Most new renewables planned	California
Most active competitive markets	California
Most active regulated and public utility markets	Colorado

Source: http://www.ucusa.org/energy

Table ES-15: Registered LEED Projects among Benchmarks

State	# Registered LEED Projects
California	141
Washington	52
Oregon	45
Rest not in top 10	

Source: http://www.usgbc.org/Docs/About/usgbc_intro.ppt.

Implications for Arizona

As input to the strategic situational assessment, the results of this benchmarking suggest the following general possibilities:

- **Arizona should consider aligning its targets for development of advanced-technology industry sectors with the regulatory priorities of the state.**
- **Arizona should consider aggressively targeting federal funding that could lead to a strong relationship with a nearby federal laboratory or to a new federal R&D laboratory in these areas.**
- **Arizona should consider making funding available for its energy office beyond the minimum required "match" for federal formula programs**.

ARIZONA'S INFRASTRUCTURE CAPABILITIES: GAP ANALYSIS

The state's infrastructure to support a sustainable systems industry was assessed through an inventory and gap analysis involving extensive interviews with industry executives; economic development providers; university faculty; nongovernmental organizations; and tribal, state, and local government leaders. In addition, several focus groups combined representatives from these sectors. Review of secondary data and interviews with key officials in benchmark regions also were conducted.

As a result of the study, gaps in the state's assets were identified that focused on five specific areas.

Arizona's Five Sustainable Systems Inventory Gaps

- Research and technology
- Product manufacturing
- Workforce development
- Business climate and infrastructure
- Market creation

Research and Technology. While the three universities have an extensive base of research on sustainable development topics, they lack coordination and collaboration among themselves or with industry. Very recently, discussions have begun to remedy this and to hopefully build a coordinated and complementary R&D portfolio, linked to state and industry needs. It also is clear that the university technology transfer offices lack expertise and experience of these market segments and are therefore unlikely to catch the next disruptive technology.

Product Manufacturing. While Arizona is known as a manufacturing state, it is largely because of strong semiconductor and aerospace clusters. This study did not find any established manufacturing cluster in any of the nine segments examined. Typically, just a few small companies are manufacturing water management systems, renewable energy systems, or green products or bioproducts; there is no formal linkage between these cluster nuclei.

Workforce Development. A key finding was the lack of cross-disciplinary academic programs that would produce trained graduates for a sustainable systems industry. Even in today's market, demand exists for engineers trained in renewable energy, energy efficiency, water management, and environmental remediation; and this trend will grow.

While a large number of undergraduate programs focus on different aspects of the environment, no program addresses the "triple bottom line" of sustainable development, and no degrees are offered. Very few graduates have specific experience with energy efficiency or renewable energy principles outside of those contained in traditional mechanical or electrical engineering programs. Also, general lack of management expertise and the poor state of the K–12 system were cited by several industry executives.

Business Climate and Infrastructure. Several key gaps were found in this area, most notably the following:

- The impact of the state tax structure in general and property taxes in particular as they relate to investments in sustainable systems.
- The lack of incubators and special eco-industrial parks that could nurture, as well as promote, new sustainable technology companies.
- Very few programs that assist entrepreneurs or companies in introducing new sustainable systems into the marketplace.
- Difficulty in securing start-up funds from private investors in the state because of lack of interest and/or understanding of new sustainable technologies.
- Reluctance of private investors to invest in new power plants or manufacturing facilities on tribal lands because they may not see a return on their investments.

Market Creation. Sustainable systems is an emerging market, and so the challenge will be to move beyond the early adopter stage of the technology adoption life cycle into the mainstream stage where significant return on investment is achieved.[25] Key gaps include the following:

- Arizona is the likely first market for most sustainable systems companies, yet there is little public awareness of the need for and value of sustainable development.
- Arizona does not have a sustainability image, which hurts local company credibility when selling out of state.
- Market opportunities on tribal reservations and in the Arizona-Mexico border region are not being utilized. These areas have much in common with third world countries, and so qualification of products and services here could well help market penetration elsewhere.
- Markets for sustainable systems exist in the EU and some developing countries such as China and India, but it takes a different skill set and approach to successfully market these regions. The smaller companies making up this industry do not have this experience.

[25] Moore, Geoffrey, *Crossing the Chasm*, Harper Business, 1992.

STRATEGIC SITUATIONAL ASSESSMENT (SWOT ANALYSIS)

Combining all the analyses—core competency, market trends, benchmarking , and inventory and gap—enables a comprehensive review of the overall strengths, weaknesses, opportunities, and threats facing Arizona in its efforts to position itself in sustainable systems.

Battelle looked at Arizona's position on sustainable systems in a general way and also examined issues and opportunities specific to industry segments.

General Strengths

The following list notes Arizona's existing strengths, the foundation and building blocks upon which to develop an effective strategy for advancing in sustainable systems.

General Strengths to Leverage

- All industry segments reviewed are aware of the need for sustainable practices to reduce their "footprints."
- Sustainable manufacturing is at an advanced stage in the area's semiconductor industry because of global drivers.
- State and local government incentive programs and/or regulations act as powerful drivers for industry to introduce sustainable technologies into electric power production, water management, and building and road construction.
- The three state universities have dominant positions in R&D in many of the components of sustainable systems. Top in water/hydrology, urban and rural ecological sciences, forest management, and environmentally benign manufacturing.
- Entrepreneurs have innovative technologies for water purification, environmentally friendly materials, and energy production.
- Rapidly growing urban areas and large tracts of rural and tribal lands provide opportunities for rapid introduction of new technologies—"a living laboratory."

General Weaknesses

In general, the following list of weaknesses in sustainable systems identifies areas in which Arizona's existing resources and activities are lacking.

General Weaknesses to Overcome

- Smaller firms are still are at the stage of introducing energy- and water-saving measures to reduce operating costs or reducing/eliminating toxic materials to meet tightened regulatory standard.
- Property tax situation penalizes business investment in sustainable systems; it does not account for lower life-cycle costs, only initial cost, which is high.
- Arizona is currently not positioned to be a major player in manufacturing sustainable systems because it has no manufacturing clusters in the key segments. Most systems are purchased outside the state.
- The three state universities are undertaking parallel programs without much interaction or collaboration across the state.
- University R&D programs in renewable energy and green materials areas are small. Utilities and industry are doing most work here, focused on the near term.
- Federal funding is split between several agencies without one central coordinating point for sustainability, presenting a challenge for funding research projects.
- There is a lack of seed and venture capital and space for new business incubation.
- University technology transfer offices do not have staff members who are experts in these fields.
- Few interdisciplinary academic programs exist to provide trained people for a sustainable systems workforce.
- No central advocate for sustainable systems industry exists in the state (closest is Environmental Technology Industry Council). NGOs tend to be focused on natural resource protection.
- Rapid urbanization is bringing issues of pollution, water shortage, and commute times, all of which impact "livability," a key factor for retention and recruitment of companies.

General Opportunities

Opportunities are those factors that have the potential to significantly advance the position of Arizona in sustainable systems. Many of the key strategic priorities and actions seek to maximize these factors for the state. Assessing Arizona's position identified the following opportunities.

General Opportunities to Build On

- Arizona (and the Southwest) will be a very significant market. Sectors growing and needing products and services include renewable power, green buildings, wastewater cleanup and recycling, and high-value crops.
- Sustainable systems products and services is a pre-emerging market in the United States, but more mature in Europe. All indications are that it will grow over the next decade, particularly in third world countries.
- An encouraging sign for sustainable systems manufacturing is the number of Arizona-based small companies with novel technologies that could "leapfrog" current applications.
- Several entrepreneurs are proposing disruptive approaches to buildings and power supplies that can build new industries.
- University strengths in sustainable systems are broad and deep and offer the potential of developing the whole product solution for customers. Collaborations are increasing.
- Proximity to Mexico offers opportunity for joint sustainable development programs, as well as a new market to serve, and access to sustainable trade programs of NADB and others.
- One-third of the land in the world available for development is arid/semiarid; therefore, as a model, Arizona can lead the way into markets in the Middle East, China, Asia, and South America for energy and water management, land use management (urbanization), transportation, agriculture, etc.
- Arizona can demonstrate the value of integrating sustainable systems across both urban and rural communities.

Threats

The following key threats involve external factors that can negatively impact the development of Arizona's sustainable systems base.

Threats to Avert

- Federal funding may be eliminated or severely cut in key areas in the future (e.g., DOE has cut solar and wind budgets for FY04).
- With its new initiatives, New Mexico could become the "model" state in the Southwest.
- California still represents the largest market for sustainable products and could retain the manufacturing base.
- Arizona relaxes its standards for energy efficiency, renewable power, and water conservation, removing the initial drivers for a sustainable systems market in the state.
- Urban growth outstrips services and infrastructure, and livability declines.
- Universities lose star faculty and programs to more aggressive, out-of-state universities, paying higher salaries.
- Venture capital availability elsewhere lures Arizona entrepreneurs out of state.
- Arizona captures the service part of the sectors but can't build the manufacturing base, which is the primary source of high-paying jobs.

OVERALL ASSESSMENT

Arizona has the foundation on which to develop a strong sustainable systems industry base. A commendable level of awareness of and commitment to sustainability principles is seen in governments, universities, industry, and NGOs, which bodes well for the future.

The state's industry is open to introducing sustainable systems into its operations, thereby helping to build a local market for new products and services. The following segments in particular are growing and need products and services: renewable power, green buildings, water cleanup and recycling, and high-value crops. These same areas are the source of the sustainable industry growth globally, so Arizona companies have the opportunity to qualify their products at home before exporting them to world markets.

However, today, Arizona is *not* positioned to manufacture the range of sustainable systems that are needed for the state and that will find even larger markets elsewhere. The following gaps should be of concern:

- No solar power manufacturing industry cluster, although there are several solar companies in the state
- No green building materials industry cluster
- Fragmented water cleanup system industry
- No greenhouse manufacturing industry to supply the growing fruit and vegetable industry
- A forest products manufacturing base in disarray, with no large anchor company.

Arizona Needs to Develop Its Manufacturing Base

- Leverage the advanced technologies in the semiconductor companies
- Transfer technology to other emerging industries, such as biotech
- Grow companies with "leapfrog" technologies
- Emphasize water management systems manufacturing
- Grow solar-power-based manufacturing

A concerted effort on behalf of the state and economic development groups will be needed to rectify this situation, or Arizona could well be a net importer of sustainable products.

Finally, these analyses suggest that seven sustainable systems "niches" are candidates for further development in Arizona:

- ***Energy Efficiency/Renewable Energy***—Focus on being a leader in energy-efficient homes/buildings via management of energy, water, and materials use. Supply small solar-, wind-, or hydrogen-powered electrical systems for homes, buildings, and factories in distributed generation systems.
- ***Water Management Systems***—Develop technologies, products, systems, and services to manage water conservation from source to sink. Focus on water desalination and ultrapure water for manufacturing processes.
- ***Sustainable Manufacturing***—Build around water management and extend beyond the semiconductor industry to biotech. Provide both an equipment and service industry.

- ***Sustainable Agriculture***—Expand the greenhouse-grown fruit and vegetable industry, using advanced water control systems.
- ***High-Value Bioproducts***—An offshoot of sustainable agriculture, whether in the field or greenhouse, and using the same basic growing system. "Biorefinery" examples include oils, cosmetic-grade materials, and fuels to eliminate air pollution.
- ***Sustainable Forest Products***—Lead a renaissance of the forest products industry in the region.
- ***Green Materials***—Provide low-cost materials for building and road construction, from lightweight concretes to asphalt.

VISION

The following vision is proposed for Arizona's future in sustainable development as seen a decade from now.

Sustainable Systems Vision

Arizona, building on its existing strengths, has become a premier national and international center for "arid-lands livability," employing sustainability principles for

- Water management, from source to sink and back again
- Harnessing the sun for power, fuel, food, and medicine
- Sustainable manufacturing and knowledge-based renewable industries, including those based on natural resources, such as forests, agriculture, and waste products.

Arizona has policies and regulations for both urban and rural areas and a business climate that encourages sustainable operations by all segments of society, so that industry growth occurs in harmony with the environment.

As a result, Arizona is the model for quality of life in arid/semiarid lands and exports sustainable systems and services worldwide, creating jobs and wealth for its citizens.

MISSION

To accomplish this vision, Arizona's mission contains two key elements.

Sustainable Systems Mission

To consolidate and grow the basic infrastructure necessary for sustainable systems industries to flourish in Arizona, building on the components already in place, namely

- Strong university/college research programs in urban and rural sustainability topics
- A receptive industry to deploy new technologies
- Active NGOs working on natural resource management
- Federal, tribal, state, and local government buildings, energy, and water programs
- Conducive geographic and environmental factors.

To sustain existing business as well as build new business, both sustaining and disruptive innovations will be demonstrated and qualified in the growing Arizona and Southwest markets, before being deployed globally in other arid/semiarid lands. Government has a role in lowering the barriers to entry for disruptive technologies.

STRATEGIC DIRECTIONS

Four key themes run through the Prospectus:

- **Partnerships between governments, NGOs, universities, and industry are essential to build the state's sustainable economy, because each industry segment will require incentives, investments and innovative technologies.**
- **The current paradigm of "use up and move on" must be changed to one of resource management and conservation for true sustainable development to flourish in the state.**
- **Urban and rural strategies for business development within the state will be different but mutually supportive. Some of the sustainable systems industry segments are more conducive to rural economies than urban, and vice versa. Likewise, small businesses, employing tens of people, will underpin rural economies, but much larger businesses, employing hundreds to thousands, are required in urban areas to support the population base.**
- **Partnerships with other states and countries will be important to build early successes, enhance reputation, and capture market share. Arizona must capitalize on its strategic position in the Southwest, partnering with New Mexico and Mexico, in particular.**

STRATEGIES FOR ORGANIZING SUSTAINABLE SYSTEMS ACTIVITIES

A total of seven linked strategies are proposed to position Arizona as an international leader in the sustainable systems industry as it evolves over the next decade.

Three strategies focus on specific industry niches to create the Arizona *"arid lands livability"* brand. Each strategy will address needs for sustaining research and technology development, demonstration and qualification of technologies in realistic pilot-plant environments, and development of appropriate policies, regulations, and incentives to encourage their adoption. These three strategies are as follows:

Strategy One: Make Arizona the "Water Management Capital" of the world.

Arizona's challenges are a microcosm of the challenges facing over one-third of the world's surface, which is arid or semiarid land. Managing water, from source to sink and back again, could be a signature for Arizona.

Strategy Two: Harness the sun for power, fuel, food, and medicine.

Arizona enjoys more than 300 days of sunshine each year, a condition that provides many opportunities to develop industries ranging from solar electricity to greenhouse-based crop production.

Strategy Three: Make Arizona a sustainable manufacturing "Center of Excellence."

Arizona is home to several companies that are part of the global semiconductor industry, which leads all industries in sustainable manufacturing—designing products for the

environment by minimizing water, energy, and material usage, and maximizing recycle and reuse of waste streams. Transfer of this experience to other industries could make Arizona the "go-to" state for future manufacturing sites.

Four additional strategies are crosscutting and address gaps that must be filled to create the necessary infrastructure for this new industry to flourish. These four strategies are as follows:

Strategy Four: Establish a national and international image for Arizona as the "arid lands livability" state.

This strategy starts at the top, with gubernatorial and legislative leadership, development of a roadmap and metrics, and an annual public forum to report and assess progress. Other activities involve communication and outreach to citizens, development of an aggressive recruiting program, and "branding."

Strategy Five: Create the business infrastructure for a sustainable systems industry.

This strategy includes addressing issues such as support of entrepreneurs in starting new technology-based companies, eliminating barriers to business expansion in the state, addressing urban and rural population growth impacts, creating supportive state and local policies, and developing the industrial infrastructure needed for cluster growth.

Strategy Six: Sustain and grow university and industry R&D.

The R&D capacity in universities and industry, both people and facilities, must be maintained at the leading edge and enhanced to address the complex science, technology, and policy issues involved with sustainability.

Strategy Seven: Develop the workforce talent pool to support the sustainable systems industry.

Workforce development begins with grade school and continues into professional life. Building on plans developed for the other technology platforms, Arizona must have actions that explicitly address the sustainable systems career opportunities.

Across these seven strategies, a series of 24 actions are proposed to be undertaken by an Arizona partnership of government, university, industry, and NGO advocates. Table ES-16 summarizes the actions proposed under each strategy.

Table ES-16: Sustainable Systems Strategies, Actions, and Time Frames

Strategy	Action	Time Frame
Strategy One **Make Arizona the "Water Management Capital" of the world**	1. Create the Arizona Water Sustainability Consortium between UA, ASU, and NAU. 2. Develop a partnership with New Mexico and Los Alamos National Laboratory to further their ZeroNet Water-Energy Initiative. 3. Launch several "signature" water demonstration projects to both enhance Arizona's image as a sustainable state and qualify products and systems for global market penetration. Focus initially on wastewater cleanup and desalination. 4. Develop a water policy framework that will be a model for arid lands sustainability throughout the world. Engage all stakeholders.	Year 1 Develop over 1 to 5 years Phase in over 1- to 3-year period; complete by year 10 Immediate—1-year goal
Strategy Two **Harness the sun for power, fuel, food, and medicine**	1. Form a Solar Center for education, research, and outreach, integrating relevant programs in the three universities, the utilities, and industry. 2. Develop and implement signature demonstrations • Renewable energy, focusing on IPP solar power installations • Energy efficiency in buildings and power plants • Bioproducts, including those derived from sea asparagus, plant-based medicines, and edible vaccines • Sustainable agriculture, focused on greenhouse-grown crops and bioproducts • Sustainable forest products, involving a broad platform ranging from biomass energy and fuels to construction materials. 3. Develop a set of supportive policies and incentives that will grow the solar-based industry and measure progress	Year 1 • 1 to 5 years • 1 to 3 years • 3 to 5 years • 2 to 3 years • 1 to 4 years Immediate—1-year goal
Strategy Three **Make Arizona a sustainable manufacturing "Center of Excellence"**	1. Evolve to a ZDM state—zero discharge manufacturing—by transferring the best practices from the semiconductor industry cluster 2. Develop and implement signature demonstrations • Identify semiconductor and/or biotech manufacturing plant for demonstration of new technologies for complete water recycle. • Develop a "green products" industry based on recyclable and/or natural materials. 3. Create a Product Development Center to develop and "showcase" sustainable products.	5-year plan Phase in over 2 to 3 years; complete by year 5 Implement over 2 years

Table ES-16: Sustainable Systems Strategies, Actions, and Time Frames (continued)

Strategy	Action	Time Frame
Strategy Four **Establish a national and international image for Arizona as the "arid lands livability" state**	1. Appoint a state "Sustainability Czar," reporting to the Governor, and the Sustainability Council, composed of thought leaders.	Immediate
	2. Create the Arizona Sustainable Systems Industry Association (ASSIA).	Transition over first two years
	3. Undertake an educational and marketing campaign to increase Arizona residents' knowledge and understanding of sustainable practices.	Develop in year 1, implement year 2
	4. Create a "Blue Ribbon" Panel to assess all current state and local standards, codes, and regulations pertaining to energy, water, environment, land use, and construction and to make recommendations on changes.	Immediate—1-year goal
	5. Market Arizona as a prime location for companies manufacturing/servicing sustainable systems, and develop the *"arid lands livability"* label.	Immediate Develop 5-year plan
Strategy Five **Create the business infrastructure for a sustainable systems industry to flourish.**	1. Implement the recommendations of the Governor's Council on Innovation and Technology (GCIT) to institutionalize the "T+3M" model for new sustainable business creation.	1- to 3-year plan phase in
	2. Create several strategically located product development centers, focused on the three segments—water, solar, and sustainable manufacturing.	3- to 5-year phase in; use existing buildings as far as possible, co-located with universities or industry
	3. Develop eco-industrial parks around sustainable industries, e.g., green construction materials, high-value bioproducts, sustainable agriculture and forest-based industries, and sustainable manufacturing.	3- to 5-year phase in; use existing development plans
	4. Attract funding from nontraditional funding sources such as private family funds, international development banks, etc.	2-year phase in with tribal demos
Strategy Six **Sustain and grow university and industry R&D**	1. Create a statewide Sustainable Systems Science and Technology (S^3T) Collaboratory that networks scientists and engineers across the state.	Immediate. Pilot for water and solar; phase in rest over time

Table ES-16: Sustainable Systems Strategies, Actions, and Time Frames (continued)

Strategy	Action	Time Frame
Strategy Seven **Develop the workforce talent pool to support the sustainable systems industry**	1. Develop a statewide workforce education strategy for sustainable industry across the state.	Immediate; integrate with other similar recommendations
	2. Increase Arizona's higher education capacity to "grow its own" skilled workers in sustainable systems.	5-year plan
	3. Increase the number of students aware of and prepared to enter science and technology fields (particularly those aimed at sustainable development).	5-year plan
	4. Increase the number of teachers who are competent in the use and application of technology in the classroom.	5-year plan

SIGNIFICANT AND CRITICAL ACTIONS FOR LONG-TERM SUCCESS

Battelle recommends a phased implementation of this ambitious program. Among the 24 actions identified in this Prospectus, eight stand out as most critical to the long-term achievement of the vision to establish Arizona as a major center of sustainable development across several research, economic development, and quality-of-life dimensions. These actions should be undertaken first. Grouped into three equal areas of emphasis, these eight actions are as follows:

Organization/Management

- **Sustainability Czar and Sustainability Council**
- **Water, energy, and sustainable product policies**
- **Image/Branding**

Technology Demonstration and Commercialization

- **High visibility "signature" demonstrations**
- **New business investment funds**
- **Eco-industrial parks and product development centers**

Research and Development

- **Arizona Water Sustainability Consortium**
- **Arizona Solar Center.**

These critical actions are to some extent interrelated, particularly as they impact Arizona's ability to capture market share and its image/brand. The following specific steps should be taken in the first year.

Organization/Management

To show the state's commitment to sustainable development, the critical first step is appointment, by the Governor, of the Sustainability Czar (i.e., Sustainability Policy Adviser). In a parallel action, legislative action to institutionalize the Sustainability Czar position would be very useful to ensure continuity across administrations.

In the first six months, the Sustainability Czar should take responsibility for converting the Prospectus into a 10-year roadmap, with annual measurable goals. It will be his/her responsibility to champion, facilitate, and monitor progress of the roadmap.

To assist the Czar in this monitoring process, it will be important to appoint the Sustainability Council, composed of "high-level" stakeholders. These volunteer thought leaders, drawn from all sectors of Arizona society, will not only serve to assess progress, provide solutions to problems, and propose enhancements, but, through their positions, also will help communicate the message that Arizona cares about its future to the citizens of the state.

A second major effort will be to assess all policies, regulations, and standards associated with sustainable systems. Given the near-term needs associated with water management, it is probably appropriate to have separate "blue ribbon" panels addressing water, energy, and materials.[26]

The foregoing activities and activities described below are tailor made for regular press releases from the Governor's Office that will start the image-building process. However, Battelle proposes that a statewide competition be held during the first 3 to 6 months to select the company that will develop the Arizona sustainability image and brand.

Technology Demonstration and Commercialization

A key to the success of this Prospectus is the qualification of new technologies/products that will create a manufacturing base in the state and the associated service sector, all producing high-wage jobs. Accordingly, it is important to start early with a few winners, and make sure that everyone hears about it. Recommendations for the first year are as follows:

- **Start at least two water projects—candidates are the AzMex High Quality Drinking Water Project, Phase 0; a small-scale demonstration of DEWVAPORATION in Phoenix; and demonstrations of new technologies in the wastewater treatment plant in Nogales.**
- **Obtain a decision by an independent power producer—Solel Solar Systems, SolarGenix, or another qualified company—to site and build a large (>1-MW) solar plant in the state.**
- **Obtain the go-ahead for the biomass plant and associated eco-industrial park in Yavapai County.**

[26] The Governor recently has announced that a special committee, the Essential Services Task Force, will evaluate fuel, electric power, natural gas, and water issues.

- **Scale up the UA neopurification water technology in a semiconductor fabrication plant demonstration.**

These signature demonstrations will be largely privately funded, but state and local support will be required in the area of help with permitting and/or providing long-term contracts for the products. Some federal funds can also be won for R&D and commercialization activities.

A second key area that must be attacked during the first year is availability of investment funds for new business start-ups. In-state funding is lacking for sustainable systems innovations, from seed to later stage investments. It is, therefore, recommended that the state approach some of the socially responsible investment organizations identified in this study and offer an incentive package for them to locate an office and invest in Arizona start-ups. This recommendation is consistent with that of the GCIT.

Also, the Arizona Multibank should be encouraged to pursue creation of an investment fund through the Rural Business Investment Program. Such a fund would be of great use to small businesses and start-ups that want to locate in rural areas.

Finally, in the first year some progress needs to be made on establishing eco-industrial parks and product development centers.

Research and Development

Sustaining and growing the R&D base in universities and industry is critical to the sustainable systems future, since it is the engine for growth of businesses and jobs. Given the image it wants for Arizona, Battelle recommends two areas of focus in the first year:

- **Formation of the Arizona Sustainable Water Consortium, which will tie the water research at UA with that at ASU, NAU, and USGS.**
- **Formation of the Arizona Solar Center, which is also an attempt to draw together a number of programs in universities and industry across the state.**

In both cases, the first year would be devoted to assembling the parts and creating the program plan, developing alliances and partnerships, and identifying gaps—staff and facilities—and sources of funding.

FINANCIAL PLAN

Table ES-17 is a 10-year financial plan and investment portfolio. This plan, which is broken into three phases—year 1, years 2 to 5, and years 6 to 10—shows the major investments that are required to implement the seven strategies. The investment needs are organized programmatically around the three areas of emphasis—organization/ management, technology demonstration and commercialization, and research and development.

The following key assumptions were made in putting this investment plan together:

- **Investments will need to cover the entire technology life cycle, from basic research to commercialization and market penetration.**
- **Investment funds will continue to flow over the three phases as projected in this financial plan.**
- **Costs of proposed programs are based on a combination of (a) estimates provided by Arizona "champions," (b) the collective experience of Battelle's Technology Partnership Practice, and (c) benchmarking similar or related programs elsewhere.**
- **Sources of funds will include private financing, philanthropic funding, university endowment, federal and state government, and industry. Details on the funding mix need to be worked out for each initiative as part of the roadmap process.**

As expected, the major expenditures are in the technology demonstration and commercialization area, with $1.25 billion proposed for signature demonstrations over the 10-year period. Key priorities among these investment items are the early demonstrations that will help establish the state's image/brand in sustainability and the disruptive technologies that will create new companies and market opportunities.

Table ES-17: Ten-Year Funding Requirements for Sustainable Systems Prospectus (in million $)

Program Area	Year 1	Years 2 to 5	Years 6 to 10	Total Three Phases
Organization/Management				
Sustainability Czar/Sustainability Council	0.5	2.5	3.5	6.5
Policy Groups/Barrier Busting Groups	0.2	1.0	1.0	2.2
Industry Association	0.2	1.0	1.5	2.7
Image/Branding	1.0	2.0	1.0	4.0
Marketing	0.5	12.0	16.0	28.5
Workforce Development	0.3	4.0	5.0	9.3
Technology Demonstration and Commercialization				
Business Infrastructure—does not include value of the funds	2.0	8.0	10.0	20
Signature Demonstrations	50	200	1000	1,250
Product Development Centers	5	20	30	55
Eco-Industrial Parks (incremental)	10	50	100	160
Research and Development				
Research Centers	1.0	14	20	35
ZeroNet Initiative with New Mexico	0.3	4	5	9.3
Collaboratory/Technical Networks	0.3	1.0	1.5	2.8
Total Projected Funding Needs	**71.3**	**319.5**	**1,214.5**	**1,605.3**

Investment Sources: While few investment sources have been confirmed at this point, it is appropriate to lay out options for financing the various activities in this Prospectus. In order of priority:

State funding will be required to underpin the basic organization and management of the Prospectus as it is translated into a roadmap as part of the 10-year state economic plan and then implemented. Also, the state will have to step up to cost-sharing the marketing campaign.

Private sector funding must pay for the major parts of the demonstration projects, although some federal support is possible where program and national interests intersect (e.g., healthy forests and hydrogen fuels). Banks, industry, and venture capital are all possible sources for demonstration and commercialization activities. Shared energy savings programs and third-party financing also are options, respectively, for financing energy efficiency projects and new facilities. There is a promise of a Small Business Investment Company through the new Rural Business Investment Program, but this must be applied for during the next six months.

Federal funding is available, not only for support of R&D (e.g., NSF, DOE, DoD, etc.), but also for economic-development-related projects such as starting product development centers and eco-industrial parks (e.g., U.S. Department of Commerce). Special funds are available for rural and/or tribal initiatives.

Foundation funding will support a number of activities, including research, policy development, and education. There are several sustainability or environmentally oriented foundations in the United States, such as the Pew and Rockefeller family trusts. University foundations also need to be considered.

International bank funding also is available for international projects, e.g., those involving Mexico. The North American Development Bank is a prime example.

Commercialization returns, over the long term, will provide reinvestment possibilities for the R&D centers to augment the federal and foundation funding.

MEASURES OF SUCCESS AND PERIODIC PERFORMANCE EVALUATIONS

As these strategies and actions are implemented over the next 10 years, it will be important to assess Arizona's overall progress in meeting its sustainability goals on a regular basis.

Therefore, as a starting point, Battelle proposes three primary, high-level performance objectives be used to help the sustainable systems initiative measure progress made toward achieving its vision and mission.

- **Arizona will establish itself as a leader in advanced water management and solar-based manufacturing and service industries and increase its employment in these sectors, doubling it by 2010.**
- **Arizona will establish at least two centers of excellence for sustainable systems R&D through collaborations with institutions that are major participants in existing and emerging arid lands sustainability programs, and outpace national**

growth rate in federal research funding in this area. One such center will evolve to "national laboratory" status by 2010.

- **Arizona will establish the business climate that encourages sustainable industry growth and institutionalize the "arid lands livability" brand by 2007 through policy and regulatory reform, broad public-private partnerships, and aggressive outreach and communications.**

The strategies contribute to the success measures, as shown in Table ES-18.

Table ES-18: Contribution of Seven Strategies to the Proposed Success Measures (H=high; M=medium)

Success Measure	Strategy One	Strategy Two	Strategy Three	Strategy Four	Strategy Five	Strategy Six	Strategy Seven
Establish leadership in water and solar industry sectors and double employment by 2010	H	H	M	M			H
Develop at least two Centers of Excellence; one evolves to national laboratory status by 2010	H	H				H	M
Establish the business climate for sustainable systems industry to flourish and the Arizona brand by 2007	H	H	H	H	H		M

Further, Battelle recommends that each objective be broken into deliverables, which can show progress annually.

Arizona should institute a process of periodically measuring its performance in achieving these objectives. One approach could be to prepare a "State of Arizona Sustainability Report" with emphasis on progress made toward the success factors listed above. This would allow the dual opportunity to focus on achievements made in the sustainable development of Arizona in general as well as achievements made in pursuing economic benefits through sustainable systems.

SUMMARY

The Sustainable Systems Prospectus represents a unique vehicle and mechanism to propel Arizona into a leadership position in sustainable development, which will develop the markets and infrastructure to encourage a new manufacturing industry to grow, create job opportunities, and provide an attractive place to live and raise a family.

The basic elements for Arizona's sustainable economy exist today. They include universities with active research programs that can serve as the engine for new technologies and products; a receptive industry that can be the first market for such products and services; state, tribal, and local governments that are concerned about water,

energy, land, forests, and the environment and are willing to do something about it; NGOs that are engaged in establishing workable policies to balance economic and population growth with protection of the environment for future generations; and favorable climate and geographic factors.

The purpose of this Prospectus, as much as anything, was to pull all these parts together into one place, so that the huge asset base can be reviewed by all the stakeholders and then appropriately leveraged into economic development. It will take a sustained partnership between governments, industry, NGOs, and universities to achieve the development of the "*arid lands livability*" label for Arizona and the associated economic growth. New research innovations must continue as current innovations are tested and qualified in signature demonstrations; and new policies, regulations, and incentives must be developed to create the business-friendly environment that is so important for new industry creation.

Some might argue that the *"arid lands livability"* label or brand is too confining, but it is important for Arizona to clearly differentiate itself from other states and regions that already have established sustainable systems industries. The state's unique position of having major urban growth, as well as rural area development occurring in land that is arid or semiarid, provides the opportunity for the "branding" that will enable huge exports, given that more than a third of the developable land in the world is in this same condition.

All this effort takes people and money. Arizona has the thought leaders in government, the private sector, and the NGOs to accomplish this successfully. This leadership must come together now to convince outside investors that this program is worth the investment. And, state government, both the Governor and the legislature, must be committed for this 10-year journey, be willing to remove barriers, and offer encouragement and incentives.

This Prospectus lays out the public and private investments that can make Arizona a leader in this next technology wave—a sustainable world. To embark on this road is probably the single most important decision for Arizona at this time. It is Arizona's opportunity to lose!

Introduction

Research universities are emerging as a key economic asset in today's global knowledge-based economy. States across the nation are increasingly seeking to leverage the science and technology assets found at their research universities as a source of competitive advantage. Research universities are becoming anchors for an exciting array of state economic development initiatives involving commercialization activities, collaborative and multidisciplinary research centers, and innovative new curriculum and educational programs needed for workforce training.

With three public research universities generating a combined $500 million annually in research funding, the opportunity to harness the economic potential of its research universities persuaded the State of Arizona to embark on an ambitious program, in partnership with the Arizona Board of Regents and the Flinn Foundation, to identify the major areas of research and develop the technology-based economic development roadmap that would help drive the state's knowledge-based economy over the next decade.

As the first phase of this initiative, in 2002, Battelle's Technology Partnership Practice was retained by the Arizona Commerce and Economic Development Commission and the State of Arizona to produce the *Science and Technology Core Competencies Assessment*, which was recently published.[27] Battelle examined Arizona's public research universities' nonbioscience areas, in particular, the physical and natural sciences. Four important "technology platforms" that will best position Arizona to take greater advantage of its research universities for economic growth were identified: advanced communications, information technology, sustainable systems, and bioengineering. These four platforms complement the three platforms identified in the Flinn Foundation-supported Arizona's Bioscience Roadmap: cancer therapeutics, neurological sciences, and bioengineering; with bioengineering represented in both studies.[28] Therefore, in total, six technology platforms for Arizona have resulted from Battelle's evaluations: advanced communications; information technology; sustainable systems; bioengineering; cancer therapeutics; and neurological sciences. The latter three areas became the basis for completing detailed bioscience business plans for Arizona. Battelle, with support from the Flinn Foundation, has assisted in the development of the plans for these three platforms.[29]

Phase II of the state's initiative, started in 2003, is to develop a full roadmap for advanced communications and information technology, similar to the bioscience effort in 2002, and, given its longer-term development path, a development and investment prospectus for sustainable systems. Together with the Flinn plans, they will provide the State of Arizona with the necessary detail and information to "catch the three technology waves"

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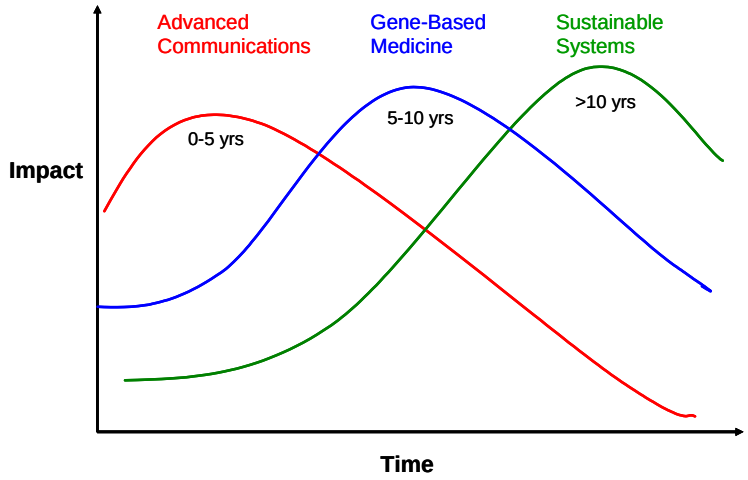
[27] *Positioning Arizona and its Research Universities: Science and Technology Core Competencies Assessment*, prepared for Arizona Commerce and Economic Development Commission, April 2003.

[28] *Platform for Progress: Arizona's Bioscience Roadmap*, prepared for the Flinn Foundation, December 2002.

[29] *Strategic Plans for Developing Near-term Technology Platform Areas of Cancer Research, Neurosciences and Bioengineering*, prepared for the Flinn Foundation, October 2003.

that will shape the future knowledge-based economy—Next-Generation Internet that will revolutionize communications; Gene-Based Medicine, including gene therapies and tissue and organ regeneration; and Sustainable Systems that will ensure economic growth and quality of life while protecting the environment for future generations (Figure 1).

Figure 1: Catching the Next Big Technology Waves



This effort also will enable the State of Arizona to work with industry to link technology and talent found in the state's public and private research organizations with the needs of recruited firms, existing and expanding firms, and new start-ups. To facilitate this, two steering committees were formed, composed of leaders from government, industry, universities, nongovernment organizations (NGOs), and economic development groups, to oversee development of the Roadmap and Prospectus and provide advice and expertise on specific opportunities and barriers.

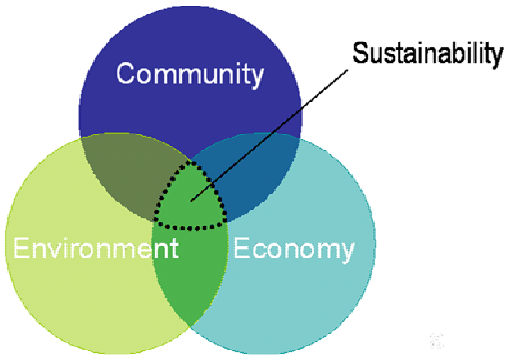
POSITIONING ARIZONA IN THE SUSTAINABILITY ECONOMY

This Prospectus provides a framework for Arizona and its stakeholders in both public and private sectors to invest in creating a whole new industry, both products and services, supporting global ***"sustainable development"***: i.e., development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This concept evolved from the efforts of a global conference held by the United Nations in Rio de Janeiro known as the Earth Summit of 1992. This watershed event was followed by many years of international debate about the sustainable development challenge. Confronted with the sustainable development challenge, the business community is recognizing that long-term success depends not only on financial performance, but also on social and environmental performance. Over the past decade, many chief executives of major companies such as DuPont, Intel, Motorola, Ford, and Johnson & Johnson have embraced "sustainability" as a business imperative.

The Triple Bottom Line

An economy is sustainable only if it respects the principles of ecology. In other words, economic growth occurs without jeopardizing the prospects of future generations to meet their needs. Creating such an economy is not a trivial undertaking and will take all segments of society working in unison toward this goal. A "sustainable enterprise" is a company that anticipates and meets the needs of present and future generations of customers and stakeholders, encompassing three dimensions known as the *"triple bottom line"* (Figure 2):

Figure 2: Triple Bottom Line



- Economic prosperity and continuity for the business and its stakeholders
- Social well-being and equity for both employees and affected communities
- Environmental protection and resource conservation, both local and global.

Sustainability includes a number of critical issues related to human and ecological welfare—climate change mitigation, pollution prevention, poverty reduction, and protection of human rights. Stakeholders in these issues include not only customers and shareholders, but also employees, local communities, regulators, lenders, suppliers, business partners, and advocacy groups.

An Emerging Market

The scientific challenges are complex and daunting—to clean up the environment, maintain the natural resource base, and reverse the effects of global warming, while at the same time ensuring economic growth and an acceptable quality of life worldwide. All the developed countries in the world have embarked on ambitious research, development, and deployment programs to address these issues. Many innovative technologies are being produced, which are fueling a growing global "sustainable systems" market, driven in large part by the increasing need for clean energy, clean water, and reduced industrial pollution.

Arizona has the companies, entrepreneurs, and university research core competencies that, collectively, form the foundation for a sustainable systems industry. The state also is a *"living laboratory"* for arid and semiarid lands, which represent over a third of developable land in the world. Arizona has both large cities (Phoenix and Tucson) and small cities with easy access to rural communities (Flagstaff) and a highly diverse population. With these assets, Arizona should be able to produce a stream of knowledge, technologies, and products that address the triple bottom line.

The state has momentum. Even as this Prospectus was being prepared, a number of positive actions were being taken to move sustainable development forward. These actions include the following:

- The U.S. Department of Agriculture (USDA) broke ground on a new Arid-Land Agriculture Research Center in Maricopa in February 2004.

- Northern Arizona University (NAU) announced a new 100,000-square-foot building for the College of Business Administration that will be Leadership in Energy and Environmental Design (LEED) certified.
- Arizona Corporation Commission is considering advancing the portfolio standards for renewable energy.
- The Forest Health Task Force is developing a more holistic approach to forest health management and community protection for Arizona.
- The Essential Services Task Force is working on evaluating Arizona's gasoline and essential services and infrastructures, including electricity, natural gas, and water.
- Several communities such as Flagstaff and Prescott have developed economic growth plans that bring in sustainability and sustainable systems.

This Prospectus is intended to help position Arizona as a leader in this emerging area, providing products and services for the global market and creating high-value jobs for Arizonans.

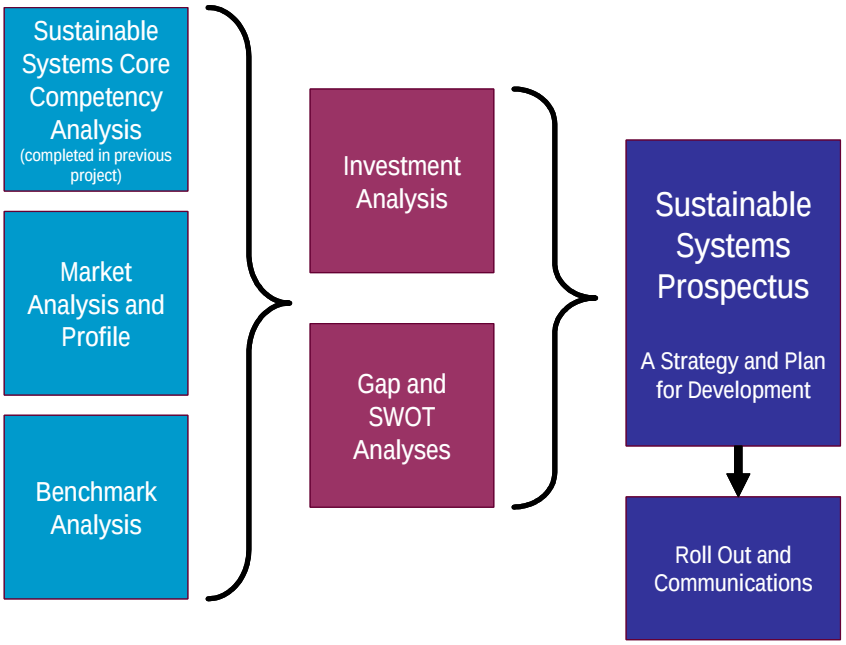
PROJECT METHODOLOGY

As indicated in Figure 3, development of the Prospectus involved the following new activities:

- Analysis of national and international market trends, developments, and opportunities on which to build Arizona's future within the segments of the "sustainable systems" industry
- A benchmarking analysis of other states and regions that are considering elements of sustainable systems to learn best practices and other lessons
- A gap analysis, through intensive university, government, and industry interviews to determine strengths, weaknesses, opportunities, and threats (SWOT) facing these industries in Arizona and an assessment of needs on which to build
- Development of a 10-year vision for Arizona in this competency area
- Development of a set of mutually reinforcing strategies and actions, including resource needs, to further position Arizona in these industries.

The results of these activities are reported in subsequent sections of this Prospectus.

Figure 3: Project Methodology Diagram



Potential Areas of Sustainable Systems Focus/Market Potential and Niches

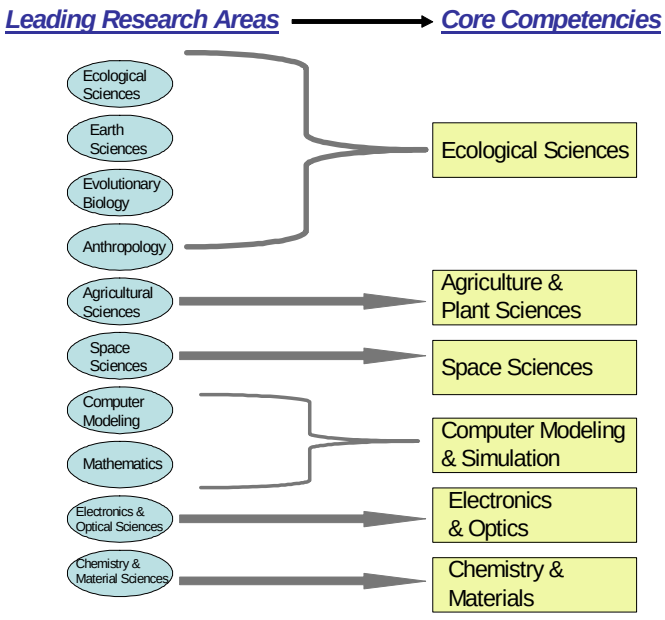
SETTING THE CONTEXT: ARIZONA'S SUSTAINABILITY RESEARCH AND INDUSTRY BASE

With an immature and diverse market such as sustainable systems, there is, at least in the early stages, more *technology push* than *market pull* as customers are convinced to embrace new, potentially disruptive technologies/products. Therefore, the research base is critical to success in creating this market.

Arizona's University Research Base

Phase I of this project identified an initial set of 10 leading research areas (outside of biomedical research) in Arizona. Further analysis of these leading research areas, informed by intelligence gathered through structured interviews with research administrators and leaders, identified six areas of core competency (Figure 4). These core competencies reflect areas of research focus in Arizona meeting the following criteria: breadth, depth, reputation, and impact on their field; competitive differentiation; ability to transcend single business areas; and hard for competitors to imitate.

Figure 4: Research Strengths to Core Competencies



Arizona's strongest core competence by far is the ecological sciences. There are three areas of world-class research and scholarship in this broad and deep competence.

- **Arid/semiarid lands ecology**—Battelle could not find another university system that possessed the same depth of knowledge.

- **Urban ecology**—The Consortium for the Study of Rapidly Urbanizing Regions at Arizona State University (ASU) is a world leader, as indicated by the extension of the remote sensing and urban environmental systems studies to many other cities around the world.
- **Hydrology and water resources**—University of Arizona (UA) is first nationally in hydrology; add to that distinction the four water centers, each dealing with a different problem area, and ASU's and NAU's contributions, and Arizona has what is arguably the world's biggest and best water resource portfolio. The only other collection of water resources that Battelle found is the memorandum of understanding (MOU) that links the water resource centers in universities in Washington, Idaho, and Oregon with Pacific Northwest National Laboratory (PNNL) and Idaho National Environment and Engineering Laboratory.

Plant sciences also has two strong research areas, which could be very powerful if integrated and linked to sustainable agriculture:

- The **Plant Genomics Institute** at UA, led by Rod Wing, sequences plant genomes, which can be used in crop enhancement and as models for human disease
- The **Arizona Biodesign Institute** at ASU, where Charles Arntzen's group is a world leader in development and manufacturing edible vaccines.

Competitors in plant sciences include St. Louis, with Washington University, Danforth Plant Sciences Center, Monsanto, and others; the Research Triangle; Cornell University; and Saskatoon, Canada. Nevertheless, it is the breadth of plant science capability at UA and ASU, including crop genetics, the use of plants as models for human disease, and edible vaccines, that makes this area an attractive competence.

The remaining four core competencies support the current manufacturing clusters and will help further sustainable manufacturing in Arizona.

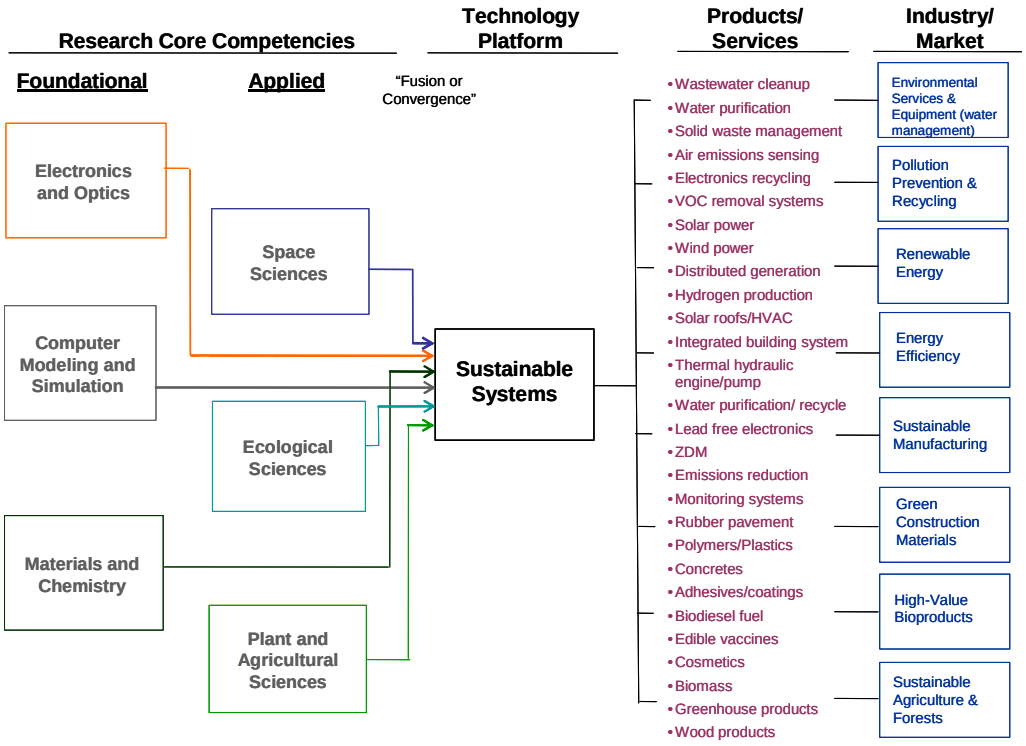
Technology Platforms

Technology platforms serve as a bridge between the research core competencies and their use in commercial applications and products. Based on Battelle's assessment, the six science and technology core competencies were ordered into ***four technology platforms*** that could be a source of innovative technologies and/or products for Arizona's economy. These are communications, information technology, bioengineering, and sustainable systems.

The sustainable systems technology platform is the starting point for this Prospectus. As shown in Figure 5, it is a robust platform potentially providing many technology product opportunities that can serve several market segments.

This platform is based on the thesis that, if economic progress is to continue, the global economy must be systematically restructured to make it environmentally sustainable. An economy is sustainable only if it respects the principles of ecology. An eco-economy would be one that satisfies current needs without jeopardizing the prospects of future generations to meet their needs.

Figure 5: The Map Linking Science and Technology with Products and Potential Markets



Arizona's Sustainable Systems Industry Base

Today, in Arizona, sustainable systems is an emerging market, which is impossible to characterize using traditional Standard Industrial Classification data. In an alternative approach, Battelle has attempted to create an industry segment strength profile for Arizona, which will provide an indication of the number of firms and employment base in each segment, using the Environmental Business International[30] classification and its own studies. The data in Table 1 were obtained from a combination of company interviews, their own designation, or Battelle's analysis; they represent, conservatively, the total number of such firms in Arizona.

[30] Environmental Business International, http://www.ebiusa.com/

Table 1: Firms and Employment Base for Sustainable Systems Market/Industry Segments

Potential Sustainable Systems	Total Companies	Total Employment
Environmental Services and Equipment	628	19,125
Pollution Prevention and Recycling	106	1,223
Renewable Energy	83	818
Energy Efficiency	54	1,462
Green Construction Materials	9	172
High-Value Bioproducts	7	205
Sustainable Agriculture and Forests	47	1,161
Total Count	**934**	**24,166**

As a conservative estimate, more than 900 companies provide sustainable systems products/services, with an employment base of approximately 24,000, in Arizona. Most of these are small businesses, employing fewer than 30 people. Not surprisingly, environmental services and equipment is the largest subsector, followed by a combined renewable energy and energy-efficiency group. No data on sustainable manufacturing are included since the companies engaged here cut across several industry sectors—semiconductors, aerospace, materials—and Battelle could find no companies that specifically provided products and services for sustainable manufacturing.

Despite its small size, this is a good foundation on which to grow an industry. By way of comparison, 10 years ago, in 1993, the employment base for the semiconductor industry in Arizona was only about 25,000; but, today it is a major industry cluster.[31]

Potential for Growth

Based on Battelle's interviews and reviews of local reports and Web sites, it is clear that there is a growing interest in sustainable systems in Arizona. The Environmental Technology Industry Cluster (ETIC)[32] is attempting to draw all the environmentally oriented firms into a membership-driven organization that represents the full breadth of environmental technologies, including carbon management, distributed power generation, environmental law, pollution control, resource recovery, and watershed management. To date, ETIC has approximately 400 members. ETIC's main objective is to promote and support development and expansion of the Arizona environmental technology industry by providing a dynamic network of public and private resources. ETIC has a strong presence in Tucson, Phoenix, and Flagstaff and has been very instrumental in introducing Arizona companies to foreign opportunities for sustainable systems, in cooperation with the state Department of Commerce.

Most sustainable systems segments showed significant activity by companies, entrepreneurs, or other advocates, producing a level of innovation that indicates potential growth over the time period of this Prospectus. Tables 2 to 7 summarize some of the key developments, and the full market profile report is contained in Appendix A.

[31] *Arizona Advanced Communications and Information Technology Roadmap*, prepared by Battelle for Arizona Commerce and Economic Development Commission, February 2004.
[32] Environmental Technology Industry Cluster, http://www.azetic.com/.

Most of the activity is in ***energy efficiency and renewable energy*** segments, largely driven by state and local regulations or incentives, such as the Environmental Portfolio Standards (EPS) for renewable energy capacity increase and the various local "green" building standards (Table 2).

Table 2: Key Developments in Energy Efficiency and Renewable Energy

Industry Segment	Key Developments
Energy Efficiency	• The **Southwest Energy Efficiency Project (SWEEP)** study concludes that the potential for energy-efficiency improvements in Arizona is tremendous and represents replacement of 12 500MW new power plants. Also, 24,100 new jobs can be created by 2020 in the industries supporting energy efficiency. • Of the 34,000 **Energy Star homes** built nationally in 2001, more than 8,000 were built in Arizona, leading the United States. • Arizona homebuilders, supported by programs from **APS and TEP**, are national leaders in offering guaranteed heating and cooling costs. • All major cities have **"green" building standards.** • Communities such as Civano, campuses such as NAU, and commercial buildings in Phoenix are all pursuing **LEED** designations. • A new solar energy firm, **So Cool Energy Inc.,** is financing new solar heating/cooling systems in commercial buildings and schools. • **Deluge, Inc.,** has developed the Thermal Hydraulic Engine, the first engine to be powered only by hot water supplied by geothermal, waste heat, or solar sources.
Renewable Energy	• **Environmental Portfolio Standard** requirements are driving the three major utilities (APS, TEP, SRP) to install solar power plants at a fast pace. Most MW generation in United States. • **Fourteen new renewable energy projects** committed through 2002—solar, wind, and biomass. TEP long-term goal is 20% solar power by 2020. • **www.AzSolarCenter.com** is getting more than 20,000 discrete hits per month, and this rate is rising almost exponentially. • **APS Solar Test and Research Center (STAR)** provides the research needs of both APS and solar equipment manufacturers. STAR is the only facility of its kind in the United States. **ASU-East** has one of the three fully accredited PV test labs in the United States. • **Solargenix** has committed financing to deploy its solar thermal technology with Arizona utilities. • **C TRADE** is a new company formed to develop Carbon Trade Credits for renewable energy projects. • **American Hydrogen Association** (AHA) is active in Arizona. Goal of AHA is to stimulate interest and help establish the renewable hydrogen energy economy by the year 2010.

The Southwest Energy Efficiency Project (SWEEP)[33] showed that the potential for energy-efficiency improvements in Arizona is tremendous and represents replacement of twelve 500-MW new power plants if implemented in residential, commercial, and industrial settings. Also, 24,100 new jobs can be created by 2020 in the industries supporting energy efficiency. Arizona leads the country in the number of Energy Star homes, which must be at least 30 percent more efficient than the 1993 Model Energy Code. Arizona homebuilders, supported by programs from Arizona Public Service (APS) and Tucson Electric Power (TEP), are also national leaders in offering guaranteed heating and cooling costs. These homes are typically 40 percent to 50 percent more efficient than required by the 1995 code.

As of 2002, there were approximately 70 solar and wind companies in Arizona, with more than 650 employees. Solar organizations and programs include the following:

- The Arizona Solar Energy Industries Association
- The Arizona Solar Energy Association
- The Solar Energy Advisory Council
- Project Sol
- Tucson Coalition for Solar.

APS is installing photovoltaic (PV) solar systems at a pace of more than a megawatt per year and has installed the largest concentrating PV system in the world, which will total more than 500 kW by the end of 2003. TEP's long-term goal is to have 20 percent of its electricity generated annually by solar power by 2020. It expects to have 4.1 MW installed by the end of 2003 and 8.6 MW at the Springerville Plant by 2010. Its technology of choice is PV from Global Solar, a local company.

An equal area of increasing interest is ***water management***, most likely exacerbated by the four-year drought and evidence of increased salinity in several aquifers (Table 3). Municipalities across the state are adding to their systems to address increased salinity. The Central Arizona Salinity Study (CASS)[34] is a coalition of water and wastewater agencies from across the state, whose mission is to provide its members with workable alternatives for a quality, cost-effective, sustainable, and reliable water supply. In its second year, the coalition is focusing on different technology assessments for application in agriculture, dairy, residential, municipal, and industrial settings. Both UA and ASU have research and development (R&D) underway to advance water management approaches for arid/semiarid regions. For example, the ASU invention, DEWVAPORATION, is being evaluated in several projects as a cost-effective desalination technology.

[33] Southwest Energy Efficiency Project, http://www.swenergy.org/.
[34] Central Arizona Salinity Study, http://www.usbr.gov/lc/region/g7000/02centralarizonaip.pdf.

Table 3: Key Developments in Environmental Services and Equipment (water management)

Industry Segment	Key Developments
Environmental Services and Equipment (water management)	• **Scottsdale Water Campus** is currently the largest facility in the nation to treat wastewater to drinking water standards using microfiltration and reverse osmosis technologies, setting high standards for the state. • Both **UA and ASU** have R&D underway to advance water management approaches for arid/semiarid regions, e.g., DEWVAPORATION. • **CIW Services** is a fast-growing local company with full engineering, manufacturing, and service capabilities, providing high-quality water treatment products and services. • **Zeta Corporation** developed the Zeta Rod, the first application of electronic treatment technology into high-volume flows of industrial cooling water and other processes.

It is hardly surprising that one main theme running through ***sustainable manufacturing*** is also water management, and this area is receiving a great deal of attention from both the semiconductor industry and universities in Arizona (Table 4). The Intel site at Chandler has an advanced water purification system that has processed in excess of 2 billion gallons of water to drinking water standards for recharge into the aquifer. The IBM and ST Microelectronics plants recycle their process water for reuse in other parts of their sites.

Ultrapure water and water conservation are two major research topics at the UA's Engineering Center for Environmentally Benign Semiconductor Manufacturing. The industry needs to purify water, in very large volumes, to an unprecedented level. A modern fabrication plant uses about 3 million gallons of ultrapure water per day. Considering that many such plants are located in the semiarid Southwest, the efficient use of water is an industry priority. A process suitable for recycling wastewater generated by the microchip industry, with its particular type of contaminants, has been developed by the Center; two pilot plants are in operation on the UA campus.

Table 4: Key Developments in Sustainable Manufacturing and Pollution Prevention and Recycling

Industry Segment	Key Developments
Sustainable Manufacturing	• Large global semiconductor companies in Arizona, such as **IBM, Intel, ST Microelectronics, and Motorola** have corporate level programs that address workplace ES&H and making their products more environmentally friendly. • **Intel, IBM, ST Microelectronics,** and others clean their process water for recharge into the aquifer or reuse in other parts of their sites. • Ultrapure water and water conservation are two major research topics at the **UA's Engineering Center for Environmentally Benign Semiconductor Manufacturing**. • **Gore** has introduced energy-efficient systems and water conservation into all its plants, including Flagstaff.
Pollution Prevention and Recycling	• The **Arizona Partnership for Pollution Prevention** provides a networking and mutual help system for companies to promote hazardous waste reduction. • **Universal Entech** designs, builds, and operates integrated solid waste management systems, including transfer stations, MRFs, IPCs, and composting. • **Pantheon Chemicals** provides environmentally safe, cost-efficient cleaning, lubricating, and pre-painting solutions as viable alternatives to existing hazardous or toxic solvents and cleaners. • **Innovative Formulations Inc**. develops innovative products that are both human and ecologically friendly.

A second theme for sustainable manufacturing is pollution prevention and recycling, with a focus on replacing or eliminating toxic materials and reducing materials use through recycling. A current focus for the semiconductor industry cluster is elimination of lead from its products, in preparation for new strict European Union (EU) standards that go into effect in 2006.

Although the semiconductor industry drives much of the research devoted to ultrapure water, pollution prevention and recycling, other fields also stand to benefit from the results. Work in certain pharmaceutical and medical areas, for example, requires ultrapure water. Also the field of biotechnology, an increasingly important activity in Arizona, will benefit from some of the techniques and technologies.

The ***green construction materials and high-value bioproducts*** segments are not well developed in Arizona. But, several small firms are producing environmentally benign or natural materials for different applications, and industry associations are promoting green products (Table 5). For example, Polylink and Strata International, separately, are developing a set of building products that integrate polymer technology and basic building materials such as cement into lightweight, inexpensive green construction materials. They are going to use these products in both single-family and multifamily homes in the state.

Table 5: Key Developments in Green Construction Materials and High-Value Bioproducts

Industry Segment	Key Developments
Green Construction Materials	• Several small firms are producing "green materials" for different applications, and industry associations are promoting green products (e.g., **AerRock, ELF, Polypore, Rastra, Polylink**). • **Strata International Group** has developed a sustainable composite building technology based on polystyrene coated on both sides with fiber-reinforced concrete. • **Rubber Pavement Association**, Tempe, represents the rubber/asphalt industry, with 30 members worldwide and four in the Phoenix area. There are two companies in Phoenix building crumb rubber producing plants. Several projects are underway with ASU.
High-Value Bioproducts	• **GEMTEK Products** is the only bioproduct manufacturer in the state. It produces biobased cleaners, solvents, lubricants, personal care and other specialties, and alternative fuels from soy, canola, corn, and peanuts. • **Integrated Energy Technologies** is interested in salt-tolerant plants such as sea asparagus, which is a potential source of oil as well as food. The Colorado Delta is a potential demonstration site. • **University research** is focused on edible vaccines (ASU), cancer drugs (UA), and nutritional products (UA). Innovative discoveries are being made.

The Rubber Pavement Association, Tempe, represents the rubber/asphalt industry, with 30 members worldwide and four in the Phoenix area. There are two companies in Phoenix building crumb rubber producing plants, Recovery Technology Group and CRM, to supply the source materials. Rubberized asphalt has been shown to have excellent fatigue properties as well as sound abatement properties.

GEMTEK Products is the only company that manufactures bulk bioproducts in the state and is probably the largest bioproducts company. It produces more than 150 products, including biobased cleaners, solvents, lubricants, personal care and other specialties, and alternative fuels from soy, canola, corn, and peanuts.

The fruit and vegetable part of the sustainable agriculture industry is of most interest, because it covers both field and greenhouse-based crops (Table 6). About 85 percent of the country's leafy green vegetables are grown in the Salinas Valley in summer and Yuma in the winter, providing a year-round business. Water is cheap in Arizona, compared with California, so there is less emphasis on conservation ($25/acrefoot compared with >$100/acrefoot). This will change if water prices increase. Salt River Project (SRP) has worked very closely over the years with irrigation customers to maximize yields/minimize water usage. Farmers served by SRP are, therefore, in a better position than California farmers (Imperial Valley) served by the Colorado River, who now face curtailments.

Table 6: Key Developments in Sustainable Agriculture

Industry Segment	Key Developments
Sustainable Agriculture	• **Cotton industry** strategy to capture high-end, high-value market for quality, with a new seed breeding program to increase both yields and quality that will demand premium prices. • About 85 percent of the country's leafy green vegetables are grown in the Salinas Valley in summer and Yuma in the winter, providing a year-round business for **Dole** and others. Farmers served by SRP are far ahead of California farmers (Imperial Valley) served by Colorado River, who now face curtailments. • Arizona has three areas falling in the top three greenhouse sites in the world, and is home to two major companies, **Eurofresh and Heinz**, involved in growing high-value fruit, vegetables, and flowers in greenhouses using hydroponics.

Agricultural land in Arizona is gradually being lost due to urbanization. Accordingly, production elsewhere in the state is shifting to greenhouses that can produce high value products, and nurseries, which is a rapidly growing industry. Arizona has three areas falling in the top three sites in the world for a greenhouse industry, and, today, Arizona is home to two major companies, Eurofresh and Heinz, involved in growing high value fruit, vegetables and flowers in greenhouses using hydroponics. Growing times are greatly reduced and water use is reduced by x 20 in this "controlled climate" horticulture.

A ***forest-based renewable industry*** is gaining momentum, and investors and entrepreneurs are proposing new secondary wood products companies based on emerging technologies. The idea is to use wood from forest thinning as a "platform" to manufacture a stream of products, from house building quality wood (2 x 4s, moldings, composite wood products) to garden products (stakes, mulch, etc.) and heat, fuel (ethanol), and/or electrical power. An important element of this industry revitalization is that 20 percent to 30 percent of the usable forests are on tribal lands, indicating possible new companies for Native American tribes (Table 7).

The new Healthy Forest Restoration Act[35] promises to fast track forest thinning projects on 20 million acres of federal land nationwide to reduce wildfire threats around rural communities and public water sources. The bill also authorizes $760 million a year, an increase of $340 million, and provides grants to develop energy from biomass cleared from overgrown forests. This should have a huge impact on Arizona's forest products industry.

[35] http://www.whitehouse.gov/infocus/healthyforests/.

Table 7: Key Developments in Sustainable Forest Products

Industry Segment	Key Developments
Sustainable Forest Products	• The **Governor's Forest Health Oversight Council** is developing policy based on sound science. • **Greater Flagstaff Forests Partnership** is an alliance of 25 academic, environmental, business, and governmental organizations in Flagstaff, dedicated to testing and adapting new approaches to restoring forest ecosystem health in the forests surrounding Flagstaff. • **A forest-based renewable industry** is gaining momentum, and investors and entrepreneurs are proposing new secondary wood products companies based on emerging technologies. • **Forest Energy Corporation** produces natural wood pellets and densified logs for building heating/hot water systems, which is far more efficient than electricity production from biomass.

NATIONAL AND GLOBAL MARKET ASSESSMENT

While Arizona and the Southwestern states in general offer great potential as markets for sustainable systems products and services, it is the broader national and international markets that determine success of any industry segment. The following, therefore, is a summary of market trends in the sustainable systems segments, both nationally and globally. More details are contained in the market profile, Appendix A.

National Markets

In terms of markets relating to sustainable systems, a major environmental industry has emerged over the past 20 to 30 years. A comprehensive study by the U.S. Department of Commerce (DOC) placed the size of the environmental industry by the late 1990s at $181 billion, with more than 110,000 companies employing more than 1.3 million Americans and more than $16 billion in exports. This translates into the environmental industry being larger than paper and allied products, petroleum refining, and aerospace and nearly as large as motor vehicles.

With maturation of the industry has come slower growth, and more recent market forecasts suggest continued mixed, but generally positive performance. Table 8 describes trends along the market segment lines that Battelle has selected, based on data from various sources, including Environmental Business International,[36] Business Communications Company,[37] and Clean Edge.[38]

[36] Environmental Business International, http://www.ebiusa.com/.
[37] Business Communications Company, http://www.buscom.com/.
[38] Clean Edge, http://www.cleanedge.com/.

Table 8: Summary of National Market Trends in Sustainable Systems

Market Segment	Trends
Environmental Services and Equipment (water management)	• Solid waste management services grew by 3.6% from 2000 to 2001. • Hazardous waste management services grew by 3.0% from 2000 to 2001; but expected to fall in revenues from $2.35 billion to $2.32 billion by 2007. Top three firms account for more than 45% of the market. • Site remediation—4.0% AAGR. • Advanced wastewater treatments—5.5% AAGR from $3.5 billion in 2001 to $4.6 billion in 2006. The United States is the fastest growing sector with 1/3 of market. Asia and Europe each have 20%. • Advanced municipal water treatment technologies (e.g., membrane filtration, ozone disinfection, UV irradiation, etc.)—23.1% AAGR. • Air monitoring equipment and sensors—9.8% AAGR. • Biotechnology for environmental management—8.3% AAGR; $103.5 million in 2001 and expected to record annual growth of 8.3%, reaching $154 million by 2006. • Emission control products will grow by 5.4% annually. • Market for filters will grow by 4.7% annually.
Pollution Prevention and Recycling	• Process and prevention technologies grew by 6% from 2000 to 2001. • Resource recovery market grew by 2.0% from 2000 to 2001.
Renewable Energy	• Market size for U.S. alternative power generation was 368 billion kilowatt hours in 2001, up 1.0% from 2000 and 6.7% from 1997. • California predicts that Renewable Portfolio Standard of 20% would create about 119,000 person-years of employment by 2010, most in geothermal and wind industries. • Global PV market continues its strong growth, at a rate of about 20% annually. • Ethanol production should increase by 15% annually as it replaces MTBE. • Wind power will expand by 79% annually and represent about 6% of the nation's electrical power by 2020.
Energy Efficiency	• U.S. savings per household (1997) were $530. • Since the 1980s, EE programs in Massachusetts saved $4 billion, created more than 20,000 new jobs in EE industry, created fewer blackouts and cleaner air, and had an estimated ROI of 2:1. • In San Jose, California, annual energy savings today are $4.5 million. • U.S. industrial sector energy savings projected to be 32.6% by 2020. • U.S. commercial sector energy savings projected to be 37.3% by 2020. • A number of national organizations and programs also encourage green buildings (e.g., LEED), and growth is expected to be 3% annual average.
Green Construction Materials	• Demand for plastic and wood-plastic composite material will grow by 13% annually. • U.S. Green Building Council forecasts an increasing trend in green building—up 3% in 2003. • Use of concrete for residential housing has grown from 8 percent to 14.4 percent in past 4 years.

Table 8: Summary of National Market Trends in Sustainable Systems (continued)

Market Segment	Trends
High-Value Bioproducts	• Green solvents—6.0% AAGR. • U.S. market for plant-derived chemicals will grow by 6.8% annually.
Sustainable Manufacturing	No specific data, but the trend in the semiconductor industry is being reflected in traditional metals and chemicals industries, the automotive industry, and the biotechnology industry. Therefore, Battelle anticipates continued growth of sustainable manufacturing and the enabling systems such as water, energy, and toxic material management.
Sustainable Agriculture	• Market for organic foods has increased approximately 20% per year.
Sustainable Forest Products	• Low prices for wood products have depressed this market, although the new housing construction sector is growing. Demand for paperboard and panels remains relatively soft. Duties and quotas have been applied to softwood imports from Canada, Russia, etc.

The projected increases in the wastewater treatment segment are noteworthy. The sewage treatment systems in many U.S. cities are outdated; they need costly upgrades to meet federal clean water standards, and new technologies that conserve water, while ensuring health and safety. Demand for improved municipal water treatment also will grow with increasing salinity of water supplies.

Another area of strong growth potential is renewable energy, particularly wind and solar PV. New Mexico, with Portfolio Standards calling for 10 percent renewable power, and California, with an expected 20 percent renewable power requirement, are projecting huge market opportunities. A recent California study projected more than 200,000 high-tech jobs in the state between manufacturing and services.[39] Governor Richardson of New Mexico recently announced, in his State of the State address, a bold new plan to construct a large commercial solar power plant by 2006.[40]

Building energy efficiency is also an area to watch as energy costs rise, bringing demands for energy savings through improved green construction materials and heating/cooling systems. A quality-of-life element also may add to the demand for smart, sustainable homes. Microsoft and Motorola are both investing in this area.

Global Markets

The global markets for sustainable products in the energy and water sectors are more mature in other countries than the U.S. Japan, Canada, and the EU countries are considered global leaders in sustainable development and have shaped their policies to take the lead in transitioning to sustainable systems.

Europe's interest in renewable energy policy goes well beyond the U.S. policy. The European drive toward sustainability stems primarily from collective environmental concerns, especially urban air pollution and climate change. Europe has modest fossil

[39] Report by Environment California Research and Policy Center, October 2003 http://www.environmentcalifornia.org/reports/renewables_jobs_7_03.pdf .

[40] http://www.governor.state.nm.us/pdf/stateofstate2004.pdf.

fuel resources, giving oil and coal firms less leverage than in the United States. The EU also has promoted and reinforced individual nation's awareness about sustainability by introducing public campaigns, tightening emission standards, providing incentives for renewable energy, implementing policies that advocate aggressive responses to climate change, and prohibiting subsidies for fossil fuels. In Japan, the main catalyst for renewable energy development has been the pursuit of energy autonomy. Climate change and the Kyoto Protocol also have influenced the Japanese government's policies.

While the United States is considered a technological leader in many areas, Canada, EU, and Japan are strong competitors and, in some areas, are taking the lead because of the countries' greater R&D spending, public awareness, and favorable governmental policies. Moreover, European decision-makers have created the market among their populations for sustainable products and have shaped the progressive policies that drive the European sustainability programs. The following provides an overview of international markets for sustainable systems, focusing on fuel cells/hydrogen, solar energy, energy efficiency, water technologies, and sustainable manufacturing in the semiconductor industry.

Fuel Cells/Hydrogen

Many countries have made commitments to future fuel cell/hydrogen use. The EU, Japan, and particularly Canada are currently leaders in fuel cell technologies and policy.

Most examples of fuel cell use have been experimental or confined to very early stages of development. Iceland has committed to become a hydrogen-based economy by 2030, which has provided the Ballard Power Systems of British Columbia with one of the largest markets for its fuel cell buses. It also prompted Daimler-Chrysler, Shell Hydrogen, and Norsk Hydro to form Icelandic Energy Ltd. to develop and experiment with the most effective ways to accomplish Iceland's goals.[41]

Case Study: Fuel Cells in Canada

Canada, particularly the province of British Columbia, has emerged as the pivotal domestic and international center of the fuel cells industry. Canada has already reaped numerous benefits resulting from its fuel cells technology.

Current economic benefits from the fuel cells industry in Canada include creation of new skilled jobs located in Canada. Its spin-off benefits include power electronics, control systems, and monitoring devices. Fuel cell companies have attracted public and private investments for research on hydrogen purification products and infrastructure. The Canadian government invested $215 million in hydrogen and fuel cells. Moreover, according to the CEO of Fuel Cells Canada, based in Vancouver, BC, the fuel cells industry has helped to create new jobs and new industry linkages. Canada's 13 fuel cell producers employ 1,640 high-skilled staff, with average annual compensation of $56,000 per employee.

Future economic benefits for Canada look even more attractive. The overall fuel cell industry growth is projected at 62 percent annually through 2005. The stationary fuel cell industry market in North America is expected to grow to $10.7 billion in 2011, producing 43,000 direct jobs and 65,000 indirect and induced jobs. The transportation fuel cell industry market in North America is expected to grow to $3.9 billion by 2011, producing 13,200 direct jobs and 19,800 indirect and induced jobs in Vancouver by 2005 and 3,180 indirect jobs. Moreover, Canada is well positioned to attract more capital investment and take a lead in providing other countries with fuel cell know-how.

[41] "Daimler-Chrysler, Shell, and Norsk Hydro: The Icelandic Experiment," World Business Council for Sustainable Development Online, http://www.wbcd.ch/casestudy/iceland/.

Fuel cells and the hydrogen future are thought to be inevitable for both the industrialized and developing world. It is estimated that by 2020 the potential market demand for fuel cells will be $145 billion worldwide and will create 15,000 jobs per billion dollars in demand for fuel cells.[42] In Canada alone, the overall fuel cell industry growth is projected at 62 percent annually though 2005.[43] The developing countries, particularly those lacking fossil fuels and concerned about the climate, represent tremendous opportunities because they might "leapfrog" traditional energy resources and proceed directly to use of fuel cells.

Solar Energy

Solar energy is now the world's second fastest growing energy source—at an average growth rate of 16 percent a year since 1990—and it is predicted to expand.[44] Global solar energy demand has grown at about 25 percent a year over the past 15 years, particularly in PV technologies. The PV solar industry now globally generates between $3 billion and $4 billion in revenues and will continue to expand. Of the global demand for solar PVs, more than 35 percent is accounted for by Japan, 25 percent by European countries, and less than 15 percent by the United States. In 1999 alone, the global solar market for PV systems reached $1 billion.[45] PVs are now being used in most of the industrialized countries and in more than 175,000 villages worldwide, producing thousands of jobs and creating economic opportunities in more than 140 countries.[46] Major energy companies such as Shell and BP endorsed solar energy by investing heavily in PVs in recent years and are planning significant increases in the solar industry.[47]

Currently, Japan, the United States, and Germany constitute 71 percent of the world market for solar PVs. In Germany and Japan, grid-connected applications accounted for more than 95 percent of the world market. Gesellschaft fur Solarenergie (GEOSOL) and Shell Solar have just announced that they will team to build what the companies said will be the largest solar power station in the world: a 5MW power station south of Leipzig, Germany.[48] Germany has now overtaken the United States as the largest net exporter of PV cells and modules, mostly for residential roof mounted systems and building integrated PVs. It also is the largest market in Europe for PV, with market share of 56 percent in 2000.[49] Japan is now the country with the most PVs installed per person.[50] In 2002 alone, the Japanese solar roof program received applications from

[42] Western Economic Diversification Canada, http://www.wd.gc.ca/mediacentre/2000/oct12–01a_e.asp.
[43] Fuel Cells Canada, http://www.fuelcellscanada.ca/Press%20releases/PWCreport.html.
[44] "Solar Power Markets Boom," World Watch Institute, http://www.worldwatch.org/press/news/1998/07/16/.
[45] "Global Solar Markets May Grow Ten-Fold by 2010," Environmental Expert News, http://www.environmental-expert.com/news/sep8-14/news3.htm.
[46] "Solar: Jobs for Today and Tomorrow," Solar Energy Industry Jobs, http://www.solardev.com/SEIA-solarjobs.php.
[47] "The BP gasoline station with PV panels on the roof," Energy Saving Now!, http://energy.saving.nu/energytoday/renewable.shtml.
[48] New Technology Week, January 26, 2004.
[49] "PV in Europe," *REFOCUS*, May/June 2003, p. 48.
[50] "Photovoltaic Industry Statistics: Countries," Solarbuzz, 2003, http://www.solarbuzz.com/StatsCountries.htm.

42,838 households.[51] Dynamic solar markets have been developed in Greece, Austria, Spain, France, Switzerland, Denmark, and Australia.

On the supply side, the amount of product shipped from PV cell manufacturers worldwide rose 37 percent in 2002.[52] More than 45 percent of the world's solar cell production is manufactured in Japan. Europe is second with 25 percent, and the United States third with 19 percent.[53] The EU countries and Japan are boosting their solar revenues by exporting technologies to developing countries where demand in energy is ever-growing.[54]

While thermal solar energy is still at the developmental state, the potential demand for thermal solar systems is significant. Markets for thermal solar energy are emerging in northern and southern Africa, western Australia, Asia, and the Middle East. The United States is currently a leader in the thermal solar industry, but Japan and the EU are becoming America's strongest competitors.

Case Study: Spain

Spain has high potential for PV and thermal energy. Electricity from PVs has recently increased dramatically in Spain, placing Spain among the leaders in PV exploitation in Europe. The Andalucia region has been particularly successful in harnessing the benefits of using solar energy. Since 1997, an ambitious program has been implemented in Andalucia to promote solar energy in order to diversify local industry, create jobs, improve the environment, and enhance the dynamics of the solar energy market. The PROSOL—the Andalucian Programmes for the Promotion of Renewable Energy Installations—has achieved significant success in that region. Since its establishment in 1997, the project has allowed for creation of more than 150 companies in the solar energy sector in Andalucia and the generation of more than 500 direct jobs. The Andalucian government has as its objective that 12 percent of the primary energy in Andalucia in the year 2010 corresponds to renewable energy sources, mostly solar.[55] To achieve this, the government plans to disseminate awareness-raising campaigns among its population, set up new installation companies, provide decentralized services, computerize services, support the development of new technologies, and create an advisory service for developers and planners. [56]

[51] "Solar Energy Global," Solarbuzz, 2003, http://www.solarbuzz.com/FastFactsIndustry.htm.
[52] Ibid.
[53] Ibid.
[54] "New and Renewable Energies," European Commission, http://europa.eu.int/comm/energy/res/sectors/photovoltaic_en.htm.
[55] "Solar Thermal Systems in Andalucia," http://www.fz-juelich.de/ptj/projekte/datapool/page/1134/OPETspain_e.pdf.
[56] "Member state/technology examples of successful penetration," Ch. 5, pp. 43–44, http://reports.eea.eu.int/environmental_issue_report_2001_27/en/Issues_No_27_05.pdf.

Continuous production improvements, falling prices, and global environmental concerns are opening up new markets for PV and thermal technologies, giving the countries that own solar technologies tremendous business opportunities. The prospects for both PV and solar thermal sectors look very good for the coming years. The global market for solar electric technology will continue to expand and is predicted to grow to $10 billion by 2010. While the focus is mostly on European countries, the United States, and Japan, high growth rates for solar are projected in developing countries that are coping with poor utility grid systems and are lacking their own solar technologies.

Energy Efficiency

Security of supply issues, rising energy and power demands, and, above all, the huge consequences of global warming are driving many countries to switch to more sustainable forms of energy production and use. The global market for energy-efficient technologies is emerging in both the industrialized and developing world. It is estimated that, in 1999, the global market for energy-efficient goods and services reached $105 billion. [57]

The energy-efficiency markets are primarily found in the United States and western Europe. However, demand for energy-efficient products is appearing in Latin America, Asia, eastern Europe, and Africa. Developing countries, in general, are experiencing an increase in energy demand due to population and economic growth, but face capital constraints in meeting these energy needs. Energy efficiency is perceived to become a crucial means to help meet rising energy demands. Developing countries will require investments of more than $100 billion to meet their energy needs. Only $12 billion of external funding is presently available, leaving a tremendous potential for energy-efficiency products to make up for the lack of domestic funds. [58] Most of the capital requirements will be needed in Asia and countries of the Former Soviet Union. This also means major business opportunities for energy-efficiency companies and a chance to reduce greenhouse gas emissions as those countries pursue rapid modernization. It is estimated that 20 percent to 40 percent improvement in efficiency could reduce demand for power by 5 percent to 10 percent in overseas markets. [59] India, for example, has recognized the importance of energy efficiency, with potential reductions in energy use of about 25 percent in its industry sector, up to 30 percent in agriculture, and up to 20 percent in transportation. The EU countries also represent a rapidly growing energy-efficiency market. As the European countries, particularly Germany and Scandinavian states, shift away from traditional energy sources, they are eager to meet their energy needs by promoting renewable and energy-saving products.

[57] "Global Markets for Energy-Efficient Products…," http://www.bccresearch.com/editors/RDEC97.html.
[58] UNIDO, https://www.unido.org/userfiles/PloutakM/7.
[59] Ibid.

Case Study: Germany

Germany has been one of the most aggressive countries in the EU to pursue sustainable systems development, including energy-efficiency measures. Germany's energy policy is increasingly influenced by environmental concerns. In this context, energy-efficiency policies have been given more and more importance. Besides reducing carbon dioxide, Germany has reaped other benefits of energy-efficiency programs: greater public awareness of the issues, greater industrial competitiveness, job creation, and money savings. The E-Team energy-efficiency project in the city of Heidelberg encouraged schools to get involved in energy-saving programs. The project started in 1995 and is ongoing. The resulting benefits have generated financial savings for the city of Heidelberg, over and above the cost of implementing the initiative. In the first year of the project, 17,000 deutsche marks (DM) were saved; 47,000 DM in the second year, and 64,000 DM in the third year. The project has succeeded in reducing energy costs, meaning savings for the schools and the city. The money saved was reinvested in energy-efficiency measures and education services. By the third year, 13 schools and colleges were involved, resulting in carbon dioxide reduction of 171 tons. Furthermore, the project encouraged learning and thinking about energy resources and emissions among students and school staff.[60]

Water Technologies

Rapid demographic changes, aging infrastructure, climate change, growing health awareness, and liberalization of water markets are increasing the worldwide demand for water quantity, quality, and infrastructure. Presently, 1.1 billion people lack access to improved water supply and 2.4 billion to improved sanitation. It is estimated that 80 percent of infectious diseases are related to water.[61] The Middle East, being the most arid and water-deficient region of the world, continues to experience grave water shortages and strained relations with its neighbors as more than 50 percent of its water comes from outside of its territories. Even countries that are rich in fresh water resources are undergoing water shortages and poor water supply. In North America and Europe, which have abundant water supply and the best sanitation systems in the world, many inland waters are polluted because of agriculture and industry.[62]

As water supply and quality is becoming a global problem, water also is turning into a booming business. Worldwide, annual industry revenues are estimated at $300 billion, with the United States accounting for more than half of that amount. This number is expected to grow as water becomes scarce and consumer markets begin to mature. Water

[60] "Heidelberg-E-Teams' Saving Energy in Schools," Case Studies, http://www.sustainability.org.uk/info/casestudies/heidelberg.htm.
[61] "Sustainable Management of Water Resources and the Aquatic Environment," UNDP's Role to Date and Strategy Framework, UNDP, 1998.
[62] 2003 International Year of Freshwater, http://www.wateryear2003.org/en/ev.php@URL_ID=4956&URL_DO=DO_TOPIC&URL_SECTION=201.html.

markets are emerging in Australia, Chile, and Mexico, with expanding potential into the Middle East, Asia, and North and South Africa. Some of the largest global water companies, such as Azurix, Suez Lyonnaise des Eaux, and Vivendi, have expanded their business to emerging water markets. The French water giant, Vivendi, now operates in numerous countries around the world, making annual revenues of more than $16 billion.[63]

Water scarcity and poor water quality have led to the rising need for transport infrastructure, wastewater treatment, and water efficiency technologies. Water and wastewater treatment demand, for example, is currently at $122 billion, constituting 40 percent of the world environmental market. The market volume for irrigation is at about $30 billion a year. Demand for micro-irrigation and low-pressure sprinkler technologies is growing at about 10 percent and will grow even more with a rising focus on water efficiency. Desalination of seawater and wastewater is experiencing 20 percent growth. Desalination is particularly sought by the southern countries where water is scarce. Currently, 13,000 desalination plants operate in 120 countries. The market, currently worth approximately $2 billion, is forecast to grow to $70 billion by 2020. Water treatment and disinfection technologies grow at about 10 to 15 percent each year, with a market value of about $5 billion a year each.[64]

Case Study: Smallholder Irrigation

More than 60 percent of current fresh water for human use is now diverted for irrigation, and, in many developing countries, irrigation's share is as high as 90 percent. There is an increasing pressure to create the "crop per drop" environment. Smallholder irrigation has been defined as one of the more effective ways to reduce water waste and spur job creation in rural areas across the globe. It is estimated that 30 percent of the rural poor could increase their incomes significantly through well-designed, country-specific smallholder irrigation programs. Markets for new micro-irrigation technologies are evolving rapidly as international demand grows. Drip irrigation techniques are already creating results. In the Ganges Delta areas of India, Nepal, and Bangladesh, irrigation techniques not only led to more efficient water use and lower soil salinity, but also increased the income of about 7.5 million poor rural people by more than $150 million per year for the past 15 years.
The drip irrigation systems in Kenya, the Deccan Plateau of India, and the Hill areas of Asia show even greater potential in environmental and economic terms.[65]

[63] "The Rising Tide of Water Markets," ITT Industries, http://itt.com/waterbook/tide.asp.
[64] Sustainable Asset Management, "Investment Opportunities in the water sector," 2001 report.
[65] "Smallholder Irrigation Market Initiative: Study on Dissemination Potential of Affordable Drip and Other Irrigation Systems and the Concrete Strategies for their Promotion," Japanese Institute for Irrigation and Drainage, 2001.

It is estimated that, in the future, annual investment of about $180 billion will be necessary to build and maintain the water infrastructure as water plays an essential role in efforts to achieve economic development. In the EU, for example, it will take investment of $170 billion euro in the next 10 years to ensure that current wastewater guidelines are met. Massive investment also will be necessary in the rest of the world, particularly the rising economies such as China and India.

Because global water resources will become so precious and so necessary for economic development, some promising investment clusters will emerge. They will include distribution and management; advanced water treatment (disinfection of water and desalination of seawater); demand-side efficiency (products for water metering, water efficiency technologies); and products related to food production, irrigated agriculture, and the production of bottled water. [66]

Sustainable Manufacturing

To obtain a sense of where sustainable manufacturing is heading, it is best to look at the semiconductor industry because it is the most innovative industry in the world. The Semiconductor Industry Association reported that semiconductor sales increased 18 percent to $166.4 billion in 2003 and will rise approximately 19 percent in 2004.[67] Together with increased performance, this industry has been very aware of environmental, safety, and health (ES&H) issues and has mounted worldwide activities to move toward green manufacturing. The World Semiconductor Council[68] represents the majority of worldwide semiconductor manufacturing and provides a unique opportunity for collaborative approaches to global issues. Established in 1997, it currently consists of the five major semiconductor manufacturer trade associations: ESIA (Europe), JEITA (Japan), KSIA (Korea), SIA (United States), and TSIA (Taiwan). ES&H drivers, technology requirements, and timescales are all included in the International Technology Roadmap for Semiconductors. Working within this framework, the large global semiconductor companies in Arizona, such as IBM, Intel, ST Microelectronics, and Motorola, have corporate-level programs that address workplace ES&H and making their products more environmentally friendly (see Appendix A for details).

Intel and Green Design

Intel is committed to conserving natural resources and reducing the environmental burden of waste generation and emissions to the air, water, and land. Intel focuses on reducing the environmental footprint of its products, processes, and operations. Green design examples include

- Lead-free semiconductors and electronics
- Environmental performance and employee safety
- Energy conservation in PCs
- Scrap wafers to solar energy.

ARIZONA'S POSITION FOR DEVELOPMENT AND ENHANCEMENT

Arizona has many of the ingredients to develop a strong sustainable systems industry base.

[66] "Investment Opportunities in the Water Sector," Sustainable Asset Management, 2001.
[67] "Global Semiconductor Sales Up 18.3% in 2003," Semiconductor Industry Association, http://www.semichips.org/pre_release.cfm?ID=299.
[68] World Semiconductor Council, http://www.semiconductorcouncil.org/.

Awareness of and Commitment to Sustainable Principles

By and large, all the **industry** segments reviewed were aware of the need for sustainable practices to reduce their "footprints." Most are still at the stage of introducing energy and water-saving measures to reduce operating costs or reducing/eliminating toxic materials to meet tightened regulatory standards. However, the corporate commitment to environmentally sound practices and their commitment to the communities they operate in are commendable and help create a sustainability culture in the state.

Commitment to Sustainable Principles

- Industry reducing their manufacturing "footprint"
- State and local government regulations and incentives
- Active NGOs working for balanced economic growth and environmental protection
- Universities involved in broad sustainability R&D

The **state government** also plays a key role in building awareness and providing the environment for sustainable practices. For example, the state's commitments to Environmental Portfolio Standards that call for use of renewable energy, the energy-efficiency standards for all state buildings, water conservation, biofuels for transportation, and pollution prevention and recycling place it among the leaders in the United States. Its incentive programs and/or regulations act as powerful drivers for industry to introduce sustainable technologies into electric power production, water management, and building and road construction.

A number of sustainable development-oriented **NGOs** have sprung up in Arizona. Valley Forward Association is a unique public interest organization that has influenced quality of life and environmental decisions in the valley since 1969. Valley Forward brings business, community, and civic leaders together to convene thoughtful public dialogue on regional issues and to promote cooperative efforts to improve the environment and quality of life in the valley, advocating a balance between economic development and environmental quality. The Nature Conservancy is an international organization committed to the global preservation of natural diversity. The Conservancy owns and manages 13 nature preserves in Arizona. The Arizona Open Land Trusts work with landowners, policy makers, advocates, and local and national partners to craft solutions to the challenges of growth that brings the loss of scenic vistas, wildlife habitat, and western heritage.

Finally, as was described in the Phase I report, the **Arizona university system's** interest in and awareness of sustainable practices is very impressive. Even since the Phase I report was published, new developments have occurred at the universities to further coordinate sustainability R&D and focus it on specific opportunities. For example, at ASU, the new Sustainable Technologies Program has been developed to incorporate a broad range of ASU scientists and engineers with industry representatives and governmental agencies. Working with international research partners from MIT, the University of Cambridge, Indian Institute of Technology-Delhi, and others, the Sustainable Technologies Program will address applying science and engineering to manage the rapid urbanization taking place in the region and around the globe. Also, Dr. Gary Nabhan of NAU has recently proposed "Advancing Sustainability in Arizona through Tri-University

Collaborations," a concept that would lead toward a statewide "collaboratory" to provide technical and policy-making assistance toward this goal.

Arizona as a Marketplace for Sustainable Systems

Arizona promises to be a very significant market for sustainable systems, although the current industrial base is not adequate to service it. The following segments, in particular, are growing and need products and services:

Arizona is a Market for Sustainable Systems

- Renewable Power
- Green Buildings
- Water Cleanup
- High-Value Crops

- **Renewable Power**—The Arizona utility plans for solar power, in particular, call for as much as 100 MW of new solar construction in the next decade. Smaller but still significant needs exist for large wind turbines and biomass plants.
- **Green Buildings**—With the current and planned residential and commercial building projections and the increasing number of builders committed to green building, the need for sustainable building systems, from energy and water to construction materials, will grow.
- **Water Cleanup—**Water recycle and reuse is a growing need in communities and will be essential for growth of the electronics industry and potentially the biotech industry. Sophisticated equipment such as that installed at the Scottsdale Water Campus is only the beginning. Increased water salinity will require improved water treatment technologies.
- **High-Value Crops—**Growing fruits and vegetables hydroponically in greenhouses in Arizona makes absolute sense. This growing industry perhaps will lead the way to "green factories" where high-value bioproducts are grown in the same type of controlled environment.

Importantly, these same areas are sources of the sustainable industry growth globally, so Arizona companies have the opportunity to qualify their products at home before penetrating the global marketplace.

Arizona as a Manufacturing Center for Sustainable Systems

Today, Arizona is *not* positioned to manufacture the range of sustainable systems that are needed for the state and that will find even larger markets elsewhere. The following examples should be of concern:

- No solar power manufacturing industry cluster, although there are several solar companies in the state
- No green building materials industry cluster
- Fragmented water cleanup system industry
- No greenhouse manufacturing industry to supply the growing fruit and vegetable industry
- A forest products manufacturing base in disarray, with no large anchor company.

Without a concerted effort on behalf of the state and economic development groups, Arizona could well be a net importer of sustainable products. This gap is being actively addressed by solar power advocates, through industry and private associations, such as the Arizona Solar Energy Industries Association, the Arizona Solar Energy Association,[69] and the Governor's Solar Energy Advisory Council.

Arizona Needs to Develop its Manufacturing Base

- Leverage the advanced technologies in the semiconductor companies
- Transfer technology to other emerging industries, such as biotech
- Grow companies with "leapfrog" technologies
- Emphasize water management systems manufacturing
- Grow solar-power-based manufacturing

The semiconductor industry is driven by global market considerations, and its sustainability programs are managed at the corporate level. Accordingly, improvements in both product and manufacturing plant conditions are introduced relatively uniformly worldwide and, as such, do not offer Arizona any competitive edge. The one exception is water management, and the existence of the UA Engineering Center for Environmentally Benign Semiconductor Manufacturing, which is pioneering new water recycling technologies for fabrication plants. This resource could be leveraged to create a distinctive competence that could encourage semiconductor industry growth and also be transferred to the emerging biotech industry, which has similar needs.

Another encouraging sign for sustainable systems manufacturing in the long term is the number of small start-up companies with novel technologies that could "leapfrog" current applications. Of particular note in the water area is the DEWVAPORATION technology being evaluated for desalination; and in the energy area, Deluge, the company now manufacturing a thermal hydraulic engine using local suppliers, and Roy McAlister, working at East Valley Institute of Technology, who has invented an anaerobic distillation process that produces hydrogen. If successfully demonstrated, these technologies could help grow the water and energy manufacturing industries. Likewise, there is a latent cluster of green construction materials companies, scattered around the state, that could well grow into a significant manufacturing base.

Most Favorable Sustainability Niches

Based on the foregoing, Battelle believes that seven sustainable systems "niches" are candidates for further development in Arizona:

- ***Energy Efficiency/Renewable Energy*—**Focus on being a leader in energy-efficient homes/buildings via management of energy, water, and materials use. Supply small solar-, wind-, or hydrogen-powered electrical systems for homes, buildings, and factories in distributed generation systems.
- ***Water Management***—Develop technologies, products, systems, and services to manage water conservation from source to sink. Focus on water desalination and ultrapure water for manufacturing processes.

[69] http://www.azsolarcenter.com/solorg.html.

- ***Sustainable Manufacturing***—Build around water management and extend beyond the semiconductor industry to biotech. Provide both an equipment and service industry.
- ***Sustainable Agriculture—***The best bet is expanding the greenhouse-grown fruit and vegetable industry, using advanced water control systems.
- ***High-Value Bioproducts***—An offshoot of sustainable agriculture, whether in the field or in greenhouses, and using the same basic growing system. "Biorefinery" examples include oils, cosmetic-grade materials, and biodiesel fuels to eliminate air pollution.
- ***Sustainable Forest Products***—Lead a renaissance of the forest products industry in the region.
- ***Green Materials***—Provide low-cost materials for building and road construction, from lightweight concretes to asphalt.

Most Favorable Market Niches

- Energy Efficiency/Renewable Energy
- Water Management
- Sustainable Manufacturing
- Sustainable Agriculture
- High-Value Bioproducts
- Sustainable Forest Products
- Green Materials

Arizona's Infrastructure Capabilities: Benchmarking, Gap, and SWOT Analyses

INTRODUCTION

This section provides a detailed examination of the key areas and resources that will assist Arizona's sustainable systems enterprise, to further its growth and reputation. To assess the state's ability to leverage continued development and investment in sustainable systems into long-term economic development, Battelle has used the following three key methodologies:

- **Benchmarking Analysis:** Factors that have proven critical to other regions in building their sustainable systems bases were determined across a benchmark of states and international regions, both leaders and competitors. Implications for Arizona were developed.
- **Gap Analysis:** An inventory of available resources was undertaken, helping to determine the gaps and barriers to both building the research enterprise and ensuring its successful translation and commercialization in the state. This inventory and gap analysis was based on interviews with industry executives, university officials, economic development officials, NGOs, consultants, and service providers.
- **Strategic Situational Assessment (Analysis of Strengths, Weaknesses, Opportunities, and Threats [SWOT]):** Based on the benchmarking and gap analyses, Battelle completed a strategic situational assessment of Arizona's enabling technological, industrial, and governmental infrastructure to support the proposed sustainable systems initiative.

BENCHMARKING ANALYSIS

Benchmarking, commonly used in the corporate and financial communities as a way of improving efficiency and calibrating performance, is just as important in planning for technology-led economic development. Benchmarking identifies, analyzes, and draws useful lessons from the practices of regions and institutions that are generally comparable along certain relevant strategic dimensions. Specifically, benchmarking can help to

The Value of Benchmarking

- Identify the competition
- Learn where you stand
- Isolate the strategic issues
- Find out what works

- **Identify the competition.** Benchmarking forces an economic development community to identify clearly those other regions against which it competes for business investment in the targeted technology sectors, in a regional, national, or international context. Benchmarking forces planners to examine, in a broad and qualitative way, who is pursuing similar strategies, how they are succeeding, or why they are stalling. This may yield important insights into how the competitive landscape looks to those in business who are making decisions on where to establish R&D partnerships or make investments.

- **Learn where you stand.** Just as a mutual fund assesses its performance against a benchmark index over time, so communities should periodically measure where they stand against an agreed-on set of benchmarks. In this quantitative sense, benchmarking can focus on certain indicators of success, often adjusted for the size of the region in question.
- **Isolate the strategic issues.** To design a strategy for technology-led economic development, any region must understand what its key choices are and how various potential uses of resources trade against each other. Examining how competing regions have positioned themselves or attacked common problems can give insight into what strategic choices must be made in view of the home region's strengths and weaknesses, and the opportunities and threats posed by the broader marketplace.
- **Find out what works.** There is no point in reinventing the wheel. Strategies and initiatives that have worked in other regions facing similar challenges can often be adapted to local conditions, avoiding the risks of investing in entirely untried approaches unless explicitly required by the local context.

How the Benchmarks Were Selected

In early discussions, Battelle and the Project Steering Committee identified several factors that needed to be broadly represented in the benchmark set in order for the exercise to be meaningful for Arizona. These factors were as follows:

- **Obvious competitor states.** The 2002 Arizona Statewide Economic Study identified a list of "benchmark" states[70] against which technology-based industry growth, tax environment, and other location-driving factors were benchmarked. This list includes not only Western, Southwestern, and Mountain neighbors, but also states in many other regions against which Arizona finds itself in competition for corporate relocations.
- **States known for relevant programming or infrastructure.** Certain states (Minnesota, New Jersey, and Oregon) are widely known for their commitment to sustainable systems. Others are known for particularly well-funded energy R&D programs that have a dual mandate for job creation (e.g., California, Connecticut, Massachusetts, New Jersey, and New York). Finally, some states have emerged as industry leaders since their environmental business associations are charter members of a national umbrella coalition (California, Colorado, Maryland, Massachusetts, New Jersey, New York, Oregon, Virginia, and Tennessee).

Benchmark Selection Criteria

- Obvious competitors
- Commitment to sustainability
- Home to relevant industry sectors
- Federal labs or other federally funded initiatives
- University centers of excellence

- **States with interest in similar industry sectors.** It also is possible to identify states with common interest in certain industrial sectors with potential for sustainable development. These include, for example, semiconductor plants with green potential

[70] California, Colorado, Georgia, Illinois, Maryland, Massachusetts, Minnesota, New Hampshire, New Jersey, New York, North Carolina, Oregon, Texas, Virginia, and Washington.

(California, Idaho, New Mexico, New York, North Carolina, Oregon, and Texas); solar (mainly the oil-dependent states of the industrial Northeast and Midwest); building technology (Minnesota and other states concerned with insulation from cold rather than heat); bioproducts/biomass (mainly states in the broader Midwest though their crops are often different from Arizona's); and environmental systems consulting (California and New York).

- **States hosting relevant federal laboratories or other initiatives.** So much of technology innovation in the sustainable sectors (and others) is driven by federal R&D funding that it makes sense to consider states that host relevant federal assets. These include, for example, relevant Department of Energy (DOE) laboratories (California, Colorado, Illinois, New Mexico, New York, Tennessee, and Washington); Environmental Protection Agency (EPA) (Georgia, Michigan, Minnesota, Nevada, North Carolina, Ohio, Oregon, and Rhode Island); Department of Agriculture (multiple states with supported programs in precision agriculture or agricultural utilization); and Commerce/National Oceanic and Atmospheric Administration (Colorado, Michigan, Oregon, and Washington).
- **States known for individual university centers of excellence.** Battelle also scanned the states for examples of university-based centers, even if they were not closely tied to statewide sustainability initiatives. Examples of nationally known research resources appear in the following universities: earth science (Colorado and Columbia); sustainable development (Michigan and Oregon State); bioproducts/biomass (Idaho State, Iowa State, Minnesota, and Washington); desert ecology (DRI/University of Nevada); green manufacturing (Alabama, Cal-Berkeley, Georgia Tech, Maryland, New Jersey Institute of Technology, New Mexico State, North Carolina State, and University of Texas-Austin).

Benchmark Selection and Capsule Descriptions

It is impossible to select a benchmark set that meets all these criteria in every case, and so the final set must include a range of communities that span the set of important characteristics as a whole. Balancing the trade-offs inherent in this choice, Battelle and the Project Steering Committee settled on six domestic and two international benchmarks: California, Colorado, New Mexico, North Carolina, Oregon, Washington, the European Union, and Vancouver, BC (Canada). Details are contained in Appendix B. The following are capsule descriptions including summaries of why the benchmark merited consideration.

California

California is known for outstanding university R&D in energy and environmental science and a vigorous business-development program funded by the California Energy Commission and other quasi-public agencies. Such programs exemplify the state's determination to turn its regulatory burdens into potential economic advantage by supporting the development of clusters of vendors of advanced technology. The state also can leverage several large DOE laboratories with relevant programming.

Colorado

Colorado has emerged as a strong resource center for solar energy, based on grass-roots adoption of solar and green building technology and the presence of NREL in Golden. The state's success at integrating university R&D with the National Oceanic and Atmospheric Administration's atmospheric science laboratories in Boulder raises the questions of when it will have similar success with NREL and what the economic impacts will be.

New Mexico

New Mexico shares much of the desert/Southwest ecology of Arizona, has developed an optics cluster around Albuquerque somewhat complementary to Tucson's, and has a common interest in semiconductor branch plants and their potential for green operation. Unlike Arizona, it is richly endowed with DOE laboratory resources and sees them as an economic driver, although so far not strongly in sustainable systems. Also, currently, it has a pro "sustainable development" Governor, who has focused his attention on renewable energy and water issues.[71]

North Carolina

North Carolina has long hosted some of the nation's leading environmental laboratories (EPA and the National Institutes of Health [NIH]) and has therefore developed a strong environmental services cluster. It also has some of the strongest university-based resources in environmental science and green and clean manufacturing, which is perceived as a strong need of the state's declining textiles sector. The state's economic development program has a clear interest in bioproducts development, oriented toward reducing farm waste and developing crops to substitute for tobacco.

Oregon

Oregon has articulated a systemic, government-wide commitment to sustainability both in government operations and as a vision for economic development. The current Governor has a Sustainability Advisor. It shares with Arizona an interest in semiconductor manufacturing and its role in a green economy and has developed especially notable quasi-public mechanisms to direct investment toward generating alternative energy and reducing greenhouse gases. As a consequence, the state is emerging as a clear center of the sustainable industries trade.

Washington

Like Oregon, Washington has explicitly embraced the economic development potential of a vision for sustainable sector development. It is the center of Northwest activity in forest and bioproducts development and serves as a nucleus of an alternative energy sector that reaches into Idaho and across the border into British Columbia.

[71] http://www.governor.state.nm.us/pdf/stateofstate2004.pdf.

European Union

In the EU, government-supported R&D efforts in sustainability have explicit economic development goals. Examples of implementation through organized industrial networks also can be seen in several locales, notably Denmark. Finally, Europe hosts widely influential NGOs such as the World Business Council for Sustainable Development, which has exerted notable influence on the business and investment practices of many global or transnational corporations.

Vancouver, BC (Canada)

British Columbia is rapidly becoming internationally recognized for its effective embrace of sustainable development, with specific programs in both the government and commercial sectors. In the public sector, planning agencies and universities are collaborating on broad public education and "futuring" programs; in the commercial sector, innovative companies are anchoring development of the fuel cell subsector of alternative energy technology. The provincial government's commitment to sustainability is influencing similar efforts being developed in Oregon and Washington.

Summary of Lessons Learned

Each of the benchmarks is a viable competitor in sustainable sectors, and several have explicit economic development goals.

Each of the six domestic and two international benchmarks has displayed an impressive commitment to sustainability as a fundamental ethic of government and private sector operations (Table 9). Each effort has been driven by different political forces and emphasizes different thrusts. What distinguishes several of the benchmarks is a commitment to make the development of sustainable industries a cornerstone of economic development strategy. The clearest articulation of this policy can be seen in recent public-policy statements by the Governors of New Mexico, Oregon, and Washington State, although none has yet fully integrated his vision into concrete economic-development programs. California has achieved a great deal of industrial development through a policy that is more implicit than explicit and extends over many years.

Table 9: State and Regional Sustainable Development Competition

State/Region	Apparent Thrusts/Interests in Sustainable Sectors	Driven by	Economic Component of Sustainability Policy	Status of Industry Sector
California	Air quality; power reliability; green buildings	State government bureaucracy over several Governors; grass-roots	Implicit strategy to make an economic virtue of regulatory necessity by levering the size of the market	Achieving high national profile
Colorado	Solar; green buildings	Grass-roots; "small is beautiful" constituency; builders	Not yet in place	Industry dominated by retail and grass-roots advocacy

Table 9: State and Regional Sustainable Development Competition (continued)

State/Region	Apparent Thrusts/Interests in Sustainable Sectors	Driven by	Economic Component of Sustainability Policy	Status of Industry Sector
New Mexico	Solar; green manufacturing	Governor and Congressional Delegation	Explicit commitment to economic growth	Industry sector still nascent
North Carolina	Green manufacturing; farm-waste reuse; forestry	Last two Governors and the public university system	So far only in the sense of service to existing industry and agriculture, and efficient use of public resources	Strong environmental services sector; others lagging
Oregon	Clean power; watershed management; climate stewardship	Governor and grass-roots	Explicit commitment to triple bottom line	Portland emerging as a center of sustainable industry trade
Washington	Clean power; power reliability; forestry/ bioproducts	Governor and grass-roots (local public utilities)	Explicit commitment to triple bottom line	Northwest/BC emerging as a center of fuel cell development
EU	Sustainable transportation, industrial ecology, environmental management systems	Top-down EU R&D programs, and bottom-up industry networks and NGOs	Explicit component of all R&D programs in Sixth Framework	Industry networks for material re-use and trading
Vancouver, BC	Urban sustainability	Provincial and regional environmental programs	Environmental industries recognized as key economic driver	Fuel cells development influencing NW "hydrogen corridor"

Simply having a state energy office that investigates renewable sectors does not distinguish the benchmarks.

Reviewing the activities of the State Energy Program (SEP) offices, it is apparent that each (including Arizona's) has conducted innovative feasibility studies and pilot deployment projects in many of the 11 program areas and nine industrial sectors supported by DOE's Office of Energy Efficiency and Renewable Energy (EERE).[72] (California does have an outsized commitment to the vehicular/fuel program areas.) As the DOE itself acknowledges, much of this work is conducted on formula funding where the nominal state matching requirements are frequently met by creative financing such as grant or loan programs actually on the budgets of other agencies. Most of the state partnering activities sponsored by EERE therefore show relatively little variation across the benchmark set. Even the "special projects" grants that SEP offices broker (though do

[72] The 11 program areas are biomass; building technologies (which administers the state partnerships programs); distributed energy and electric reliability; federal energy management; vehicular technologies; geothermal technologies; hydrogen, fuel cells, and infrastructure; industrial technologies (administers the OIT program); solar technologies, weatherization; and wind/hydropower. The nine industry sectors are agriculture, aluminum, chemicals, forest products, glass, metalcasting, mining, petroleum, and steel.

not have to match) show little variation that cannot be explained by population, except possibly in New Mexico which achieves the same level as Arizona with a far smaller population. Where some variation appears is in the total amount of state partnership funding flowing to *all entities* in the state. In the two most recently reported fiscal years, Colorado and Washington State perform out of proportion to their size—probably reflecting the presence of DOE laboratories willing to partner with private sector firms (Table 10).

Table 10: Energy Programs

State/Region	Million Solar Roof Non-State Partners	Clean City Coalitions	DOE Allied Partners in-State	Industry of the Future Partnerships	$ FY03 Special Projects to SEP Agency	FY01–02 Total $ to State from BTS (millions)	2002 Population (millions)
Arizona	3	2	1	4	$689,756	$3.6	5.5
California	13	12	7	2	$3,474,630	$47.7	35.1
Colorado	5	3	5	5	$430,632	$46.4	4.5
New Mexico	1	1	0	3	$577,790	$4.2	1.9
North Carolina	2	1	7	4	$574,996	$10.3	8.3
Oregon	0	2	5	6	$208,722	$6.2	3.5
Washington	2	1	5	3	$774,468	$25.1	6
EU	Not applicable						
Vancouver, BC	Not applicable						

Sources: Million roofs: http://www.millionsolarroofs.org/partnerships_statelocal/.
Clean Cities: http://www.ccities.doe.gov/coalitions_map.shtml.
Allied partners: http://www.oit.doe.gov/bestpractices/partners.cfm.

None of the benchmarks has yet fully aligned its energy programming with economic development, but several are on the cusp.

One of the benchmarks, California, has gone well beyond minimal requirements for the federal SEP and added substantial budgetary authority for conducting R&D (not just deployment) of alternative energy technology. Although this funding has had evident impact on developing technology vendors in the state, it has not been matched by an explicit commitment from state economic-development agencies to target the sustainable industries for development, recruitment, and retention. Oregon has given itself the capacity through a public benefit fund to address the same goals, but so far the fund is supporting deployment and not R&D. However, this may change as the Governor's commitment to the triple bottom line filters through the system. North Carolina, New Mexico, and Washington State have all supplemented the activities of their SEP offices with the industrial extension and outreach functions of their state university systems. In Washington, energy technology is being added as a sector targeted by the technology partnership agency. None of the benchmark states has put all the elements together, but it seems likely that one or more shortly will (Table 11).

Table 11: Energy Benchmarks

State/Region	Additions to Basic State Energy Program	Role of State Agency for Tech-Based Development	Comment
California	$62 million energy R&D program (public-benefit funded) Air quality and pollution prevention programs with their own R&D budgets	Minimal. Some attention to environmental services cluster in San Diego	Purchasing power of California Power Authority used to nurture alternative power companies
Colorado	None	No lead agency for tech-based development. Governor now focusing on IT and bioscience clusters	Advocacy community is pushing a public benefit fund
New Mexico	State-funded, university-managed environmental research consortium handles pollution-prevention leadership	Agency has minimal programming. Most efforts at regional (Albuquerque) level	Gubernatorial interest likely to redirect cluster initiatives
North Carolina	Department of Administration stewards the state government and university system pollution-prevention initiatives Sustainability one key thrust of NC State Industrial Extension Service and outreach programming	Expansion of state-funded biotech center to embrace forest biotechnology Funding available for sustainable crop development and waste management through tobacco settlement board	Environmental services sector has long been a recruiting target based on R&D strengths at universities, RTI, and federal labs. May be connections with existing ag-biotech cluster
Oregon	Permanent sustainability board Energy Trust (public benefit fund, but no R&D component) Climate Trust Clean Diesel initiative in pollution prevention agency	No lead agency for tech-based development	Likely that Governor's new thrust may place stronger emphasis on company formation
Washington	Strong involvement of WSU cooperative extension in SEP functions Bonneville Electric Foundation as a substitute for a public-benefit fund	Addition of energy technology to mandate of Washington Technology Center Continued emphasis on precision forestry and agriculture in state supported programs at UW and WSU	
EU	N/A	N/A	Explicit component of Sixth Framework R&D program
Vancouver, BC	N/A	N/A	

The benchmarks are differentiated by how they are using federal facilities—including those in other states.

In addition to presence of an R&D fund, one of the factors that distinguishes the benchmarks from each other is presence of federal laboratories with capacity in sustainable systems and the resources to participate in partnership activities funded either through the lab itself or by headquarters operations in Washington, D.C. (Table 12). Of the benchmark set, Colorado has the federal laboratory (NREL) possibly best suited to a major component of this work, but seems to have been the least aggressive in learning

how to use it. New Mexico has been very aggressive in squeezing spin-offs and industrial collaboration from its laboratories (Sandia and Los Alamos), but so far has not targeted the sustainable sectors to a great extent.

Table 12: Targeted Federal Funding

State	Major Federal Facilities Levered	How	Comment
California	UC-managed labs (esp. LBNL, Los Alamos)	The labs feed UC research networks on energy and environment	Not a major component of California strategy to date
Colorado	NREL	Underutilized to date; mainly collaborations with School of Mines	State has not yet learned to effectively leverage the lab or its commercialization function
New Mexico	Sandia and Los Alamos	Extensive commercialization and industrial service commitments by both lab managers (Lockheed-Martin and UC)	To date, the labs have been worked for other clusters (optics, microsystems), but sustainable sectors are sure to follow, starting with PV and solid-state lighting
North Carolina	NIEHS and EPA labs in RTP	RTP has been marketed to environmental service firms	Federally supported NC Solar Center, though not a federal lab, has boosted state's visibility
Oregon	EPA and Forest Service Labs at Oregon State University BPA	Extensive university–agency research collaborations, including joint use of facilities and staff	An MOU between Oregon University System, Oregon Health and Sciences University, and PNNL has produced several joint programs, including the state's first ***Signature Research Center for Multiscale Materials and Devices,*** which will revolutionize energy and chemical systems
Washington	PNNL BPA	PNNL organizes a bioproducts consortium, and BPA helps fund renewables deployment	PNNL supports a significant environmental services cluster in Tri-Cities and throughout the state and is a major contributor to state hydrogen and fuel cell initiatives
EU	N/A		
Vancouver, BC	N/A		

Several states refuse to be constrained by whether or not they currently host a relevant laboratory. For example, California leverages the University of California's (UC's) operation of Los Alamos; Oregon makes sure its university sector does business with Washington-based PNNL. In fact, in the renewable sectors, the Northwest behaves very much like an integrated region—something not evidenced in the Southwest.

Finally, several states show how targeted federal funding, even when not a formal federal laboratory, can be important. For example, New Mexico's delegation followed up its enormous investment in Sandia's microsystems infrastructure with a designation of the

laboratory as headquarters for the DOE solid-state lighting initiative, which has direct relevance to sustainable sectors. And, in North Carolina, which has major NIH and EPA laboratories in environmental science, designation of the NC Solar Center as home to the national Database of State Initiatives for Renewable Energy (DSIRE) has significantly raised the profile of the state.

Traditional benchmarks show California as the clear leader.

California is the only one of the six benchmark U.S. states to meet all four criteria articulated by the Union of Concerned Scientists (UCS) for development of a renewable energy sector—and it also is one of three in the set to have at least one formal program targeted at industrial recruitment in the sustainable sectors, as tracked by the DSIRE (Table 13). As a consequence, California leads the benchmarks in most UCS award categories,[73] with a distant second-place performance in new renewables by both Oregon and Washington, whose efforts are grass-roots dominated (Table 14). Finally, data published by the Green Building Council show California again a dominant leader, followed by Washington and Oregon (Table 15).

Table 13: California, the Benchmark Leader

State	Renewable Standards (UCS)	Public Benefit Fund (UCS)	Net Metering (UCS)	Disclosure (UCS)	Recruitment incentives (DSIRE)
Arizona	X	X	X	X	
California	X	X	X	X	X
Colorado			X	X	
New Mexico	X	X	X		
North Carolina					X
Oregon		X	X	X	
Washington			X	X	X
EU	N/A				
Vancouver, BC	N/A				

Source: UCS categories: http://www.ucsusa.org/energy.
DSIRE: http://www.dsireusa.org/summarytables/.

Table 14: Benchmarks in UCS Award Categories

Category	Benchmarks in Winning Set
Most total funding for renewables	California
Highest annual average funding per kilowatt-hour over life of fund	California
Disclosure required outside comprehensive restructuring	Colorado
Most new renewables installed	California, Washington, Oregon
Most new renewables planned	California
Most active competitive markets	California
Most active regulated and public utility markets	Colorado

Source: http://www.ucsusa.org/energy.

[73] There are 19 in all.

Table 15: Registered LEED Projects among Benchmarks

State	# Registered LEED Projects
California	141
Washington	52
Oregon	45
Rest not in top 10	

Source: http://www.usgbc.org/Docs/About/usgbc_intro.ppt.

Implications for Arizona

As input to the strategic situational assessment, the results of this benchmarking suggest the following general possibilities:

- **Arizona should consider aligning its targets for developing advanced-technology industry sectors with the regulatory priorities of the state.** In other words, just as California has exploited its need for stringent auto emissions standards to support development of a vigorous alternative fuels sector, and just as North Carolina has established similar economic thrusts that leverage its acknowledged need to control waste from agricultural operations, Arizona should focus technology development efforts that are synergistic with established regulatory priorities such as improved conservation in the water supply system. This is only one example of the strategic connections that could be established.
- **Arizona should consider aggressively targeting federal funding that could lead to new federal R&D in these areas.** Benchmarking demonstrates that the federal laboratory system, which is so critical to supporting technology partnerships with emerging companies, is not static. Laboratories are created based on trajectories established years earlier through line-item appropriations or other targeted efforts at developing critical expertise. Arizona should aim at building federal support for high-priority research expertise and meantime should develop outreach agreements with relevant federal facilities even if located in other states. In particular, arrangements with NREL in Colorado and the two New Mexico DOE laboratories seem highly appropriate.
- **Arizona should consider making funding available for its energy office beyond the minimum required "match" for federal formula programs**. Enhanced funding would allow the state to accelerate its programs to encourage installation of clean energy systems, thus driving market demand for technologies such as PV and others well suited to the Arizona climate and geography. Increased funding also would allow the state to support R&D in these technologies so that the supply chain is not dominated by installers and wholesalers, but includes high-value-added participants like manufacturers and developers. Additional funds also would position the state better for DOE "special project" funding and other partnership arrangements from the DOE Office of EERE.

GAP ANALYSIS

This inventory and gap analysis involved conducting extensive interviews in the state with industry executives, university officials, economic development providers, consultants, NGOs, and service providers. In addition, Battelle reviewed other studies and reports and secondary data on the general area of sustainability and sustainable development, including making contacts in some of the benchmark states and regions. Finally, to shape the strategic assessment, several focus group sessions were conducted with more than 70 representatives from industry, universities, Arizona's Tribal Nations, NGOs, and service providers.

As a result of the study, gaps in the state's assets were identified that focused on five specific issues.

Arizona's Five Sustainable Systems Inventory Gaps

- Research and technology
- Product manufacturing
- Workforce development
- Business climate and infrastructure
- Market creation

Research and Technology

While the three Arizona universities have an extensive base of research on sustainable development topics, they lack coordination and collaboration. Very recently, discussions have begun to remedy this and to hopefully build a coordinated and complementary R&D portfolio, linked to state and industry needs.

AREA	GAPS
Research and Technology	• The three universities undertake parallel programs with little coordination to date. • Very little renewable energy and green materials R&D exists in universities; mainly technology development in utilities and industry. • University centers are generally not available for industry use, and industry is little involved in the research. • University tech transfer offices do not have skills in this area. • There is no national laboratory in Arizona. • Arizona does not have a history of long-term investment in technology development.

Another interesting gap is the low level of renewable energy research conducted by the universities. Small solar and wind power programs exist, but the largest focused effort is in industry and is therefore directed toward proprietary development and deployment.

In general, few connections exist between universities and the specific sustainable systems industry segments. The ASU DEWVAPORATION and the UA Neopurification Water technologies are notable exceptions. However, most of the current innovative technologies being commercialized come from elsewhere, many from out of state.

Another gap, also noted in the benchmark study, is the absence of a national laboratory in Arizona to attract major federal research programs. Colorado, California, and New

Mexico have national laboratories that are leading large sustainability programs, e.g., renewable energy at National Renewable Energy Laboratory (NREL), energy-efficient buildings at Lawrence Berkley National Laboratory (LBNL), and the new ZeroNet water-energy initiative at Los Alamos National Laboratory.

Finally, it is clear that the university technology transfer offices lack expertise and experience of these market segments and are therefore unlikely to catch the next disruptive technology.

Product Manufacturing

While Arizona is known as a manufacturing state, this reputation is largely because of strong semiconductor and aerospace clusters. Battelle could not find any established manufacturing cluster in any of the nine segments examined in this study. Typically, only a few small companies are manufacturing water management systems, renewable energy systems, green products or bioproducts; and there is no formal linkage between these cluster nuclei.

In many cases, Battelle was told that needed systems were purchased from out of state or often from abroad. For example, some solar power plant components are imported from Japan, and all greenhouses are manufactured in Holland.

Manufacturing in Arizona

Arizona spent $14,560 annual average investment per employee in manufacturing in 2001, which placed the state 6th in nation.

It should be noted that the Environmental Technology Industry Cluster (ETIC) is attempting to draw all sustainable systems companies together and provide the necessary advocacy for this emerging industry, but it has as members less than half the companies Battelle believes constitute this industry.

AREA	GAPS
Product Manufacturing	• State's sustainable industries are not linked in any formal way with each other or with academia. • There is no single, influential advocate for sustainable industries (ETIC is closest). • No sustainable systems manufacturing/service clusters exist in the state; most equipment is purchased out of state. • Sustainable manufacturing is practiced by the semiconductor industry, but not routinely transferred to other industries.

A final point is that the semiconductor industry in Arizona, as elsewhere in the world, is a leader in sustainable manufacturing, routinely introducing new technologies for energy and water conservation, as well as eliminating toxic materials from its production cycles and maximizing material recycling. These "best practices" are shared within the industry, but are not routinely transferred to other industries that could benefit from them.

Workforce Development

A key finding for workforce development was the lack of cross-disciplinary academic programs that would produce the trained graduates for a sustainable systems industry. Demand for cross-disciplinary skills exists today in the energy, environmental remediation, and manufacturing industries. A large number of undergraduate programs focus on different aspects of the environment. Examples include the following:

- Environmental engineering as part of civil engineering, including water and wastewater treatment, air pollution control, and hazardous waste management, at ASU and NAU
- Environmental sciences, including biology at UA
- Forestry at NAU
- Renewable natural resources with a major in wildlife, watershed, and rangeland resources at UA.

But, no program addresses the triple bottom line of sustainable development, and no degrees are offered.

Graduate degree programs, both master's and Ph.D.'s, can be broader. At ASU, for example, urban engineering is emphasized, combining ecology with industrial growth; at NAU, natural resource management around development of arid lands; and at UA, broad water management issues in arid lands.

AREA	GAPS
Workforce Development	• Few university and college programs are producing graduates with needed multidisciplinary skills. • Weak K–12 system will limit ability to produce students who will pursue careers in this area.

Very few graduates have specific experience with energy-efficiency or renewable-energy principles outside of those contained in traditional mechanical or electrical engineering programs. Battelle did find, however, that ASU-East and NAU have some courses in energy management, and Yavapai Community College trains its students in green building design and construction and is planning to have them build additional buildings on campus.

The lack of management expertise, generally, was cited by several industry executives. They wanted the state's business schools to focus more on training technology business professionals.

A direct analogy to the situation with sustainable systems is a 2003 survey by Battelle, which found that gaps in Arizona's educational system have created a mismatch in demand and supply for bioscience workers, another emerging industry for the state. Specifically, these gaps are as follows:

- As job opportunities in health care and research laboratories expand, few educational programs address this need—and those that do suffer from low enrollment.
- While Arizona stands out in the growth of biology graduates—up 15 percent in the state between 1996 and 2001 compared with one percent nationally—few of those students get the kind of hands-on lab training they need.
- The medical devices industry is Arizona's largest nonclinical bioscience sector, but training is lacking in regulatory affairs and quality standards critical to the industry.
- Arizona has seen a sharp decline in doctorate and master's degree programs in the biosciences, just as demand for postdoctoral scientists is expanding.

The report indicates that the problems may be a result of a "disconnect" between bioscience employers and educational institutions on several factors: what kinds of curricula are needed, a lack of capacity in bioscience education, and limited awareness of career opportunities in the biosciences.

The poor state of the K–12 system also was mentioned on many occasions in the interviews as a major issue in providing qualified students to the undergraduate programs. However, preparation for a career in sustainable systems is not the issue here, but rather the general state of science and mathematics education at all grade levels. In a survey of employers conducted by the Morrison Institute for Public Policy in 2001, 52 percent of the respondents indicated that talented prospective workers have reservations about locating in Arizona because of poor-performing public schools.

Public Schools in Arizona—National Rankings

2003 Data (% at or above Proficiency)

Reading:

4th Grade 23%; Rank 43

8th Grade 25%; Rank 41

Math:

4th Grade 25%; Rank 39

8th Grade 21%; Rank 40

The situation in the schools on Native American reservations is of concern to tribal leaders; their primary objective is to keep the young people in school long enough to obtain their general equivalency diplomas. Very few go on to college; and only two tribal colleges exist in the state, on Navajo and Tohono O'Odham lands.

Business Climate and Infrastructure

The following key perspectives on the state of the business climate and business infrastructure for a sustainable systems industry were obtained largely from the focus groups, where this area was a very popular topic, generating much discussion:

- A number of industry executives raised concerns regarding the impact of the state tax structure in general and property taxes in particular as they relate to investments in sustainable systems. New technologies such as solar heating/cooling systems or solar electric systems are more expensive initially, yet are more cost effective based on a life-cycle analysis. Nevertheless, it is the up-front investment that goes into the property tax base and leads to an increase in property taxes.

AREA	GAPS
Business Climate and Infrastructure	• Venture capital funds and angel networks are not investing in sustainable systems firms. • Gap exists in pre-seed to seed funding. • There are no designated eco-industrial parks. • No specialized incubators or application centers exist to showcase sustainable products. • There are few economic development assistance programs to drive early adoption of sustainable systems. • Tax structure is not favorable for investment in sustainable systems. • Rapid urbanization is taxing the basic infrastructure—roads, water supplies, schools, natural resources, and the environment. • It is very difficult to obtain private funds to build electric power or manufacturing plants on tribal property.

- The lack of incubators and special eco-industrial parks that could nurture, as well as promote, new sustainable technology companies was cited by entrepreneurs as an obstacle to their ability to get their companies off the ground. With respect to incubators, places are needed where products can be manufactured in small runs, tested, and qualified. In special eco-industrial parks, waste streams from one company can be feedstock for another company. This synergism helps start-ups get off the ground. On a positive note, the UA has just started an incubator and park that could be developed into an eco-industrial complex.
- Battelle found very few programs that assist entrepreneurs or companies in introducing new sustainable systems into the marketplace. Traditional small-business assistance programs are not very helpful to technology-based start-ups. Tribal representatives noted the lack of support in introducing renewable energy businesses on their lands. Several executives recommended that the current state procurement policies be expanded to mandate the use of green materials and energy and water conservation systems in all state buildings, as a means to provide "early adopters." Another idea, practiced in San Diego, is to expedite the permitting process for private builders who agree to follow green building standards that include these requirements.
- Representatives of the NGOs pointed out that the state does not have a uniform water-use policy. Negotiations therefore are at local levels, where decisions in one area can have impact on quality of life in other areas. Industry executives agreed that a uniform state water-use policy would help them in planning for expansion.
- Entrepreneurs find it very difficult to secure start-up funds in the state because of lack of interest and/or understanding of their new sustainable technologies. Most projects appear to be self-funded, supported by federal grants, or supported by a large company partner, all of which have restrictions. The gaps are at the very early

pre-seed stage, as well as later seed capital stages, in the so-called "valley of death" domain of technology commercialization (i.e., $200,000 to $2 million range).

- Rapid urbanization in the Phoenix valley, Tucson, and border regions was cited several times as a potential issue for retaining and recruiting companies, which look at commute times, pollution, water supply, and schools as part of their quality of life assessment when considering relocation or expansions. To address this challenge, ASU has integrated its research on urban ecology into the Consortium for the Study of Rapidly Urbanizing Regions.[74] The Consortium not only conducts research, but also performs on-site applications regarding the interdependencies between growing infrastructure needs of rapidly urbanizing regions and the well-being of associated communities.
- Tribal leaders reported that private investors were reluctant to invest in new power plants or manufacturing facilities on the reservations because they did not see an adequate return on their investments. Consequently, the only businesses are those supported by the federal government or casinos.

Market Creation

The sustainable systems market is emerging; therefore, many questions were raised about how to penetrate and grow market share when the market is new and ill defined. Past experience with disruptive technologies (and sustainable systems meet that definition since they change the current paradigm) shows that "innovators" and "early adopters" are crucial to entering the market, dominating one or more niches, and beginning mass production.[75] This Technology Adoption Life Cycle or TALC has been surprisingly resilient over the years. Innovators represent 2.5 percent of the population, and early adopters represent 13.5 percent. In contrast, the early and late majorities represent 34 percent each of the population.

AREA	GAPS
Markets	• Arizona market for renewable energy is still very small. Opportunities in tribal reservations or in border region are not being explored. • Public awareness of value of sustainable living is low. • Arizona does not have an image or brand for sustainable development. • Markets are pre-emergent in United States and developing countries; more mature in EU. Different skill set is needed to sell globally.

[74] CSRUR, http://ces.asu.edu/csrur/index.htm.
[75] Moore, Geoffrey, *Crossing the Chasm*, Harper Business, 1992.

So, the question for many was how to move beyond the early adopter stage into the area where several gaps exist for sustainable systems and significant return on investment can be achieved:

- Arizona is seen as the first market for most sustainable systems companies. In fact, some entrepreneurs have moved to the state specifically to make and sell their technology. However, in general, they felt that there was not much public awareness of the need for and value of sustainable development (especially in the Phoenix area) and, as noted earlier, not much help in selling locally.
- Arizona does not have a sustainability image, unlike Oregon, Colorado, or Washington State. In fact, some went so far as to say that Arizona's image was the opposite—"Use up and move on." This hurts local company credibility when selling out of state (i.e., Arizona is not "walking the talk").
- Market opportunities on tribal reservations and in the Arizona-Mexico border region are not being explored. These areas have much in common with third world countries, and qualification of products and services here could help marketing elsewhere.
- Markets for sustainable systems exist in the EU and some developing countries, but it takes a different skill set and approach to successfully market these regions. Arizona Department of Commerce has an international trade group that assists companies abroad, and ETIC organizes trade missions for its members, but much more assistance is needed if Arizona-based companies are to be successful in the global marketplace.

STRATEGIC SITUATIONAL ASSESSMENT (SWOT ANALYSIS)

Combining all the analyses—core competency, market trends, benchmarking, and inventory and gap—enables a comprehensive review of the overall strengths, weaknesses, opportunities, and threats facing Arizona in its efforts to position itself in sustainable systems.

In the following, Battelle has looked first at Arizona's position on sustainable systems in a general way, before examining issues and opportunities specific to industry segments.

General SWOT

Strengths

The following list notes Arizona's existing strengths, the foundation and building blocks upon which to develop an effective strategy for advancing in sustainable systems.

General Strengths to Leverage

- All industry segments reviewed are aware of the need for sustainable practices to reduce their "footprints."
- Sustainable manufacturing is at an advanced stage in the area's semiconductor industry because of global drivers.
- State and local government incentive programs and/or regulations act as powerful drivers for industry to introduce sustainable technologies into electric power production, water management, and building and road construction.
- The three state universities have dominant positions in R&D in many of the components of sustainable systems. Top in water/hydrology, urban and rural ecological sciences, forest management, and environmentally benign manufacturing.
- Entrepreneurs have innovative technologies for water purification, environmentally friendly materials, and energy production.
- Rapidly growing urban areas and large tracts of rural and tribal lands provide opportunities for rapid insertion of new technologies—"a living laboratory."

Weaknesses

In general, the following list of weaknesses in sustainable systems identifies areas in which existing resources and activities are lacking for Arizona.

General Weaknesses to Overcome

- Smaller firms are still are at the stage of introducing energy- and water-saving measures to reduce operating costs or reducing/eliminating toxic materials to meet tightened regulatory standards.
- Property tax situation penalizes business investment in sustainable systems; it does not account for lower life-cycle costs, only initial cost, which is high.
- Arizona is currently not positioned to be a major player in manufacturing sustainable systems because it has no manufacturing clusters in the key segments. Most systems are purchased outside the state.
- The three state universities are undertaking parallel programs without much interaction or collaboration across the state.
- University R&D programs in renewable energy and green products areas are small. Utilities and industry are doing the most work here, focused on the near term.
- Federal funding is split between several agencies without one central coordinating point for sustainability, presenting a challenge for funding research projects.
- There is a lack of seed and venture capital and space for new business incubation.
- University technology transfer offices do not have staff members who are experts in these fields.
- Few interdisciplinary academic programs exist to provide trained people for a sustainable systems workforce.
- No central advocate for sustainable systems industry exists in the state (closest is ETIC). NGOs tend to be focused on natural resource protection.
- Rapid urbanization is bringing issues of pollution, water shortage, and commute times, all of which impact "livability," a key factor for retention and recruitment of companies.

Opportunities

Opportunities are those factors that have the potential to significantly advance the position of Arizona in sustainable systems. Many of the key strategic priorities and actions seek to maximize these factors for the state. Assessing Arizona's position identified the following opportunities.

General Opportunities to Build On

- Arizona (and the Southwest) will be a very significant market. Sectors growing and needing products and services include renewable power, green buildings, wastewater cleanup and recycling, and high-value crops.
- Sustainable systems products and services is a pre-emerging market in the United States, but more mature in Europe. All indications are that it will grow over the next decade, particularly in third world countries.
- An encouraging sign for sustainable systems manufacturing is the number of Arizona-based small companies with novel technologies that could "leapfrog" current applications.
- Several entrepreneurs are proposing disruptive approaches to buildings and power supplies that can build new industries.
- University strengths in sustainable systems are broad and deep and offer the potential of developing the whole product solution for customers. Collaborations are increasing.
- Proximity to Mexico offers opportunity for joint sustainable development programs, as well as a new market to serve, and access to sustainable trade programs of the North American Development Bank (NADB) and others.
- One-third of the land in the world available for development is arid/semiarid; therefore, as a model, Arizona can lead the way into markets in the Middle East, China, Asia, and South America for energy and water management, land use management (urbanization), transportation, agriculture, etc.
- Arizona can demonstrate the value of integrating sustainable systems across both urban and rural communities.

Threats

The following key threats involve external factors that can negatively impact the development of Arizona's sustainable systems base.

Threats to Avert

- Federal funding may be eliminated or severely cut in key areas in the future (e.g., DOE has cut solar and wind budgets for FY04).
- With its new initiatives, New Mexico could become the "model" in the Southwest.
- California still represents the largest market for sustainable products and could retain the manufacturing base.
- Arizona relaxes its standards for energy efficiency, renewable power, and water conservation, removing the drivers for a sustainable systems market in the state.
- Urban growth outstrips services and infrastructure, and livability declines.
- Universities lose star faculty and programs to more aggressive, out-of-state universities, paying higher salaries.
- Venture capital availability elsewhere lures Arizona entrepreneurs out of state.
- Arizona captures the service part of the sectors but can't build the manufacturing base, which is the primary source of high-paying jobs.

SWOT Specific to Industry Segments

The following are the results of an analysis of individual industry segments in Arizona.

Environmental Services/Equipment (water management)

The area of water management offers Arizona many opportunities to create a dominant market position. Arizona has innovative new technologies, a small manufacturing base, and receptive customers in both local government and industry.

STRENGTHS

- ETIC helps with international marketing.
- Four water purification companies exist in the state, including CIW Services, the fastest-growing private, homegrown company.
- The Scottsdale Water Campus is the largest municipal facility in the world to treat raw wastewater to potable quality for aquifer recharge.
- Large federal and state investment exists in water-related R&D, from arid lands and hydrology research to environmentally benign semiconductor manufacturing.

WEAKNESSES

- There is only one manufacturing plant for water equipment.
- There is no uniform state water-use policy, nor political will to develop one.
- State “brain trust” is not used to develop science-based decision support systems.
- Little attention is paid to solid waste issues by general population; plenty of land exists for landfills.
- Public awareness of value of sustainable development is lacking.

OPPORTUNITIES

- Small companies are emerging with novel environmental technologies.
- CASS identified major desalination needs in the state, requiring water cleanup.
- Mine waste cleanup is a new business opportunity.
- Continuing drought will force precision agriculture into drip irrigation and grow the greenhouse crop industry.

THREATS

- State does not develop a water-use policy framework and value-pricing structure.
- Manufacturing industry lost to New Mexico and/or Mexico.
- State tax policy continues to penalize company investments in new equipment.

Pollution Prevention/Recycling

Large companies such as Intel, IBM and Gore have installed pollution prevention equipment in their plants. However, this practice has not extended to all manufacturing plants, and the local market for such equipment is small. There are several "grass-roots" organizations promoting pollution prevention, but no significant manufacturing cluster in the state. Nevertheless, several small companies, dispersed through the state, manufacture environmentally friendly products and recycle products ranging from wood to computers.

STRENGTHS

- State has tax credits and other incentives for pollution prevention and recycling equipment installation.
- Waste Management has the largest facility in the United States for computer recycling.
- Intel Project XL brought advanced P2 systems into the state.
- Universal Entech and Pantheon Chemicals are "poster" firms for environmentally friendly materials and systems.

WEAKNESSES

- No industry clusters exist, only a few isolated firms.
- There are no incentives to recycle—plenty of landfills.
- Only one recycler for small businesses exists; transportation costs are too high.

OPPORTUNITIES

- Arizona has an initiative in electronics recycling that could grow as standards for landfills are tightened.
- New California law requires "tax" on PCs to support their recycle. Gold Circuit could benefit.
- Tucson has experience with mining and reclaiming landfills, which can be "exported."

THREATS

- Companies move to New Mexico and/or Mexico due to high labor costs.
- Pressure to relax standards increases.

Renewable Energy

This area is strong for Arizona, given the climate, the Environmental Portfolio Standards that favor solar power, and three utilities working actively to advance the technologies and make them economically viable. Opportunities to grow the fraction of renewable energy produced in the state will increase as prices come down; and Arizona could export solar power, with its "green credits," to other regions in the future. However, the state will have to address the absence of major manufacturing of renewable power systems. The few small firms currently manufacturing specialty solar and wind power systems are subcritical as a "cluster" and cannot serve even the state market needs.

STRENGTHS

- Three major utilities are skilled in renewable energy, on and off grid.
- Fourteen new projects are committed through 2002.
- Environmental Portfolio Standards require utilities to add renewables, particularly solar power.
- Solar resource is best in the United States.
- APS has unique Solar Test and Research Center, STAR.
- PV Test Center is at ASU-East.
- New innovations exist in power production.
- High interest in solar is exhibited by active Web site and five solar advocate organizations.

WEAKNESSES

- Little renewable energy research exists in the universities.
- There is little coordination among groups and no single advocate.
- "Green Power" is more expensive, so <1/2 percent of customers buy it.
- Low EPS requirement exists for renewable energy.
- Equipment installation raises property taxes.
- With no manufacturing base, most systems are purchased out of state.

OPPORTUNITIES

- Interest is increasing in small, distributed generation (DG) for new construction.
- Population growth demands new power sources.
- Disruptive technologies are available to advance solar and biomass.
- Tribes represent off-grid, subsidized economies that would be great locations for DG demos.
- Arizona could become carbon dioxide neutral with a combination of carbon sequestration in forests/agriculture and renewable energy.
- Arizona could create renewable hydrogen and/or methane fuel industry from biomass.

THREATS

- Utilities may not be able to attain Portfolio Standards for solar installation (100 MW).
- Investment is not made in renewables; Arizona relies on energy efficiency and fossil fuels.
- Other states such as Nevada dominate solar; Northwest dominates hydrogen fuel initiative.
- Industry retention/recruitment is impacted by potential higher energy prices.

Energy Efficiency

This is another great area for growth in Arizona, driven initially by the local demand for new homes and commercial buildings, but later exportable to other states and countries. Adoption of green building standards has enabled Arizona builders to be leaders in the United States in energy-efficient homes. While the number of LEED buildings is still relatively small, plans are in place to greatly increase their number, including entire school and university campuses. Also, several innovative building materials and solar heating/cooling systems are now being introduced into the green building portfolio.

STRENGTHS

- Green building standards are implemented in major cities.
- Arizona Energy Strategic Alliance promotes LEED buildings.
- Entrepreneurs are interested in major projects and new firms.
- Solar heating/cooling technologies are available in the state.
- State has alternative fuel vehicle law.

WEAKNESSES

- Little or no manufacturing base exists in the state.
- Legislation is not enabling (e.g., CC&Rs constrain solar panel use).
- Property taxes are based on high up-front investment, not low life-cycle costs.

OPPORTUNITIES

- Arizona's economy is growing, requiring new construction. Solar companies are ready.
- Arizona could model San Diego, which accelerates permitting for firms that use green building standards.
- SWEEP represents large savings and many new jobs through energy efficiency.
- Arizona could lead in developing "arid lands LEEDS" and "Energy Star" building standards.

THREATS

- U.S. economy weakens further and impacts markets outside state.
- Semiconductor and embedded systems manufacturing moves offshore.
- Biotech doesn't take off in state as projected, so little new manufacturing base is added.

Sustainable Manufacturing

The expertise and experience with sustainable manufacturing lie mainly in the area's semiconductor companies that deploy water, energy, and materials conservation measures, developed largely through global industry collaborations. The opportunities here focus on further developments in water, energy, and materials management, supported by the Arizona universities, which will enable growth of the current industry cluster and transfer of those technologies to other industries, such as biotech.

STRENGTHS

- All large global semiconductor firms in Arizona have "design for environment programs."
- UA has major NSF/industry center for environmentally benign manufacturing.
- Strong university expertise exists in water management.
- New environmentally conscious entrepreneurs are starting companies.

WEAKNESSES

- Emerging biotech industry has not fully embraced sustainability principles.
- Smaller firms are responding only to regulatory needs.
- No recognized cluster exists in sustainable manufacturing services/equipment.

OPPORTUNITIES

- Semiconductor industry can grow with advances being made in water and energy conservation; sustainable manufacturing lowers costs over plant life cycle.
- Tech transfer to biotech could make Arizona the place to build next-generation biotech plants.
- Effective water management is the state discriminator that could make it a world leader.

THREATS

- Semiconductor manufacturing goes offshore, and the biotech industry does not develop as expected.
- High up-front costs limit smaller firms from adopting sustainable manufacturing.
- Eliminating waste may cost jobs.

Green Construction Materials

This is a small segment today, but could grow with the introduction of new technologies and service two important subsectors, namely energy-efficient buildings and improved roadways. For example, replacement of portland cement with extruded fly-ash cement for building construction could revolutionize home construction; and the millions of waste tires piling up along the U.S.-Mexican border region present an opportunity for crumb rubber plants that can feed the growing rubber-pavement cluster in Phoenix.

STRENGTHS

- Several small companies have innovative materials for buildings.
- Phoenix-Tempe is the center of the rubber pavement industry with a small cluster.
- Universities are engaged in research on materials and construction processes.

WEAKNESSES

- There is no critical mass; only small start-ups are producing building materials.
- Markets are not developed nationally.
- There are few incentives for homeowners to buy.
- Not all building standards contain green material requirements.

OPPORTUNITIES

- State government purchasing requirements could include green construction materials to help build local market.
- Arizona and other states could expand use of rubber pavement following 5-year test period.
- Rapid housing growth and need for roads in the Southwest will provide initial markets.

THREATS

- Materials are not accepted in building codes/standards.
- Cheaper imports are available from Asia or Mexico.
- New companies move to Mexico for low-cost labor.

High-Value Bioproducts

This also is a small industry segment today, but has good potential for significant growth if the state can capitalize on the university research into natural products, plant genomics, and edible vaccines. “Green factories” and “biorefineries” could become realities in Arizona under the right set of conditions.

STRENGTHS

- Arizona has a strong university R&D base and interest in plant genomics, edible vaccines, and plant-based drugs.
- Entrepreneurs are interested in projects to produce high-value chemicals and fuels.
- State investments in TGen and other biosciences can be leveraged.

WEAKNESSES

- There is no critical mass; less than 10 firms and only one manufacturer operate in the state (Gemtek).
- There is a weak link back to Arizona university science and technology.

OPPORTUNITIES

- Greenhouse-based crop industry provides the infrastructure and experience for the “green factory” and “biorefinery.”
- Land availability and drip irrigation enable special crop growth in oases, without cross-pollination.
- Carbon credits provide for greenhouse crop production.
- “Genetically modified organism (GMO)-free” zones provide incentive for isolated area like Arizona.

THREATS

- Concerns about genetically engineered foods transfer to all GMOs; restrictions on use are applied.

Sustainable Forest Products

This industry segment will likely undergo significant change as a result of the Healthy Forest Restoration Act. A renewed industry could emerge based on a platform of products from wood to fuel, obtained from forest thinning.

STRENGTHS

- Strong forest science programs exist at NAU and UA.
- Greater Flagstaff Forests Partnership is dedicated to testing and adapting new approaches to restoring forest ecosystem health.
- Governor's Forest Health Oversight Council is developing guidelines for forest-based industry.
- A few companies are using forest thinning for profitable energy production.

WEAKNESSES

- The forest products industry in Arizona is in disarray; very few companies are still in operation. There is no large anchor company.
- Forests are mainly on federal and tribal lands, so they have barriers to use.

OPPORTUNITIES

- Healthy Forest Restoration Act promises to fast track forest thinning projects on 20 million acres of federal land nationwide. Budgets are now available for demos and research.
- Forest-based Renewable Industry is gaining momentum; investors and entrepreneurs are proposing new secondary wood products companies.
- Twenty to 30 percent of the usable forests are on tribal lands, so there are possible new companies for Native American tribes.

THREATS

- Foreign competition from Canada, Russia, and China reduces demand for domestic wood. Industry growth in general remains slow.
- Healthy Forest Restoration Act will change the way USFS has to operate and manage

Sustainable Agriculture

The chance of a greatly expanded greenhouse-based, value crop industry is high, given Arizona's climate and the success of the companies already operating in the state. Other field-based agriculture also will continue; but, for growth to occur, water management must be emphasized more than it has been to date.

STRENGTHS

- Arizona has the Controlled Environment Agriculture Center at UA.
- Eurofresh and Heinz grow high-value fruit, vegetables, and flowers in greenhouses using hydroponics.
- Strong winter salad crop industry exists in Yuma.

WEAKNESSES

- Rapid urbanization is eliminating agricultural land at a rapid rate.
- Dairy industry is consolidating and moving farther away from urban centers. There are energy, water, and waste issues and also those related to availability of feed crops.
- Beef ranching is a disappearing industry.

OPPORTUNITIES

- Arizona has three areas falling in the top three greenhouse sites in the world. Potential exists for high-value crops.
- Phyto and bioremediation plants are a potential for greenhouse cultivation.
- Arizona could capture the growing interest in organic crops and medicinal/culinary herbs.
- Farmers served by SRP are far ahead of California farmers served by Colorado River, who now face curtailments.

THREATS

- Cotton and other crops are facing strong foreign competition.
- Salt buildup in land could limit traditional crop growth.
- Water could limit growth if not managed properly.

Key Strategies and Action Plans

INTRODUCTION

This Prospectus has, as its overall theme, **"Arid Lands Livability."** This section describes strategies and action plans that will build the sustainable systems industry base, provide a supportive infrastructure, and help create Arizona's sustainability brand.

VISION

The following vision is proposed for Arizona's future in sustainable development as seen a decade from now.

Sustainable Systems Vision

Arizona, building on its existing strengths, has become a premier national and international center for "arid lands livability," employing sustainability principles for

- Water management, from source to sink and back again
- Harnessing the sun for power, fuel, food, and medicine
- Sustainable manufacturing and knowledge-based renewable industries, including those based on natural resources, such as forests, agriculture, and waste products.

Arizona has policies and regulations for both urban and rural areas and a business climate that encourages sustainable operations by all segments of society, so that industry growth occurs in harmony with the environment.

As a result, Arizona is the model for quality of life in arid/semiarid lands and exports sustainable systems and services worldwide, creating jobs and wealth for its citizens.

MISSION

To accomplish this vision, Arizona's mission contains two key elements.

Sustainable Systems Mission

To consolidate and grow the basic infrastructure necessary for sustainable systems industries to flourish in Arizona, building on the components already in place, namely

- Strong university/college research programs in urban and rural sustainability topics
- A receptive industry to deploy new technologies
- Active NGOs working on natural resource management
- Federal, tribal, state, and local government buildings, energy, and water programs
- Conducive geographic and environmental factors.

To sustain existing business as well as build new business, both sustaining and disruptive innovations will be demonstrated and qualified in the growing Arizona and southwest markets, before being deployed globally in other arid/semiarid lands. Government has a role in lowering the barriers to entry for disruptive technologies.

STRATEGIC DIRECTIONS

Four key themes run through the action plans:

- Partnerships between governments, NGOs, universities, and industry are essential to build the state's sustainable economy because each industry segment will require incentives, investments, and innovative technologies.
- The current paradigm of "use up and move on" must be changed to one of resource management and conservation for true sustainable development to flourish in the state.

Key Themes

- Partnerships between governments, NGOs, universities, and industry
- Resource management rather than resource exhaustion
- Different strategies for urban and rural areas
- Partnerships with other states and countries

- Urban and rural strategies for business development within the state will be different but mutually supportive. Some of the sustainable systems industry segments are more conducive to rural economies than urban, and vice versa. Likewise, small businesses, employing tens of people, will underpin rural economies, but much larger businesses, employing hundreds to thousands, are required in urban areas to support the population base.
- Partnerships with other states and countries will be important to build early successes, enhance reputation, and capture market share. Arizona must capitalize on its strategic position in the Southwest, partnering with New Mexico and Mexico, in particular.

STRATEGIES FOR ORGANIZING SUSTAINABLE SYSTEMS ACTIVITIES

Battelle has developed a total of seven strategies to position Arizona as an international leader in the sustainable systems industry as it evolves over the next decade.

Three strategies focus on specific industry niches to create the Arizona "arid lands livability" brand. Each strategy will address needs for sustaining research and technology development; demonstrating and qualifying technologies in realistic pilot-plant environments; and developing appropriate policies, regulations, and incentives to encourage their adoption. These three strategies are as follows.

Strategy One: Make Arizona the "Water Management Capital" of the world.

Arizona's challenges are a microcosm of the challenges facing more than one-third of the world, which is arid or semiarid land. To continue the pace of economic growth required by Arizona's population, the state must address water issues holistically at both policy and technology levels. Managing water, from source to sink and back again, could be a signature for Arizona.

Strategy Two: Harness the sun for power, fuel, food, and medicine.

Arizona enjoys more than 300 days of sunshine each year, a condition that provides many opportunities to develop industries ranging from solar electricity to greenhouse-based crop production. Arizona can be a major exporter of solar-based products.

Strategy Three: Make Arizona a sustainable manufacturing "Center of Excellence."

Arizona is home to several companies that are part of the global semiconductor industry. Unquestionably, this industry leads all industries in sustainable manufacturing—designing products for the environment by minimizing water, energy, and material usage and maximizing recycle and reuse of waste streams. Transfer of this experience to other knowledge-based industries as they evolve could make Arizona the "go-to" state for future manufacturing sites.

These three strategies are manifested as specific opportunities to capture market share in eight sustainable industry segments, as shown in Table 16.

Table 16: Three Strategies Create Market Share Potential in Eight Industry Segments

Industry Segment	Strategy One	Strategy Two	Strategy Three
Environmental Services and Equipment	• Water desalination • Wastewater recycle		
Renewable Energy		• Solar electric power, heating and cooling • Biomass power	
Energy Efficiency		• Solar hot water, heating and cooling • Power plant efficiency • Smart buildings	
Sustainable Manufacturing	• Full water recycle and reuse in manufacturing		• Growth of semiconductor and embedded systems industry • Transfer technology to emerging biotech industry
Green Construction Materials			• Green materials manufacturing
High-Value Bioproducts			• Manufacture of oils, cosmetics, vaccines etc.
Sustainable Agriculture	• Drip irrigation crops • Greenhouse hydroponics	• Biomass-based fuels and energy • Organic crops • Natural products and medicines	
Sustainable Forest Products		• Biomass-based fuels and energy	• Wood products platform for eco-industrial park

To create new markets for Arizona technologies, the business model will focus on potentially disruptive technologies in each industry segment and utilize Arizona's or the Southwest's marketplace as sites to demonstrate and qualify components before exporting the "whole product" to arid/semiarid areas of the world. Global market opportunities are developing rapidly as indicated by Table 17, which summarizes Battelle's detailed examination of trends in arid countries/regions (Appendix A). Following North America, the Middle East, China, and Australia offer the best opportunities overall; but, Mexico and India also should be targets for solar and water equipment.

Table 17: Global Market Opportunities for Arizona Sustainable Systems

Technology/ Product	Middle East	China	Australia	Latin America	S.E. Asia	Central Asia
Water						
Desalination	X		X			
Wastewater	X			X		
Cleanup/Recycle	X	X		X		X
Drinking water	X	X				X
Irrigation						
Energy Efficiency						
Homes, buildings	X	X	X			
Renewable Energy						
Solar	X	X	X	X	X	
All other		X	X			
Sustainable Agriculture						
Crop production	X	X				X
Sustainable Forest Products		X	X	X		

X's represent more significant areas of concern and investment and near-term markets.

To ensure stakeholder commitment, to the extent possible, existing and/or planned projects should be used to jump start the process. A number of special technology/product application demonstrations will be undertaken to qualify the sustainable systems for commercial deployment. The purpose of these demonstrations is twofold: First, to qualify the product, service, or system for the global market; and, second, to begin the process of "branding" Arizona as a leader in sustainable development. These will be high-visibility demonstrations of advanced or disruptive technologies, conducted by Arizona-based partnerships within the state or nearby, and accompanied by an appropriate communication and outreach plan.

Four additional strategies are crosscutting and address gaps that must be filled to create the necessary infrastructure for this new industry to flourish. These four strategies are as follows.

Strategy Four: Establish a national and international image for Arizona as the "arid lands livability" state.

This strategy starts at the top, with gubernatorial and legislative leadership, development of a roadmap and metrics, and an annual public forum to assess and report progress.

Other activities involve communication and outreach to citizens, development of an aggressive recruiting program, and "branding."

Strategy Five: Create the business infrastructure for a sustainable systems industry.

This strategy includes addressing issues such as support of entrepreneurs in starting new technology-based companies, eliminating barriers to business expansion in the state, addressing urban and rural population growth impacts, creating supportive state and local policies, and developing the industrial infrastructure needed for cluster growth.

Strategy Six: Sustain and grow university and industry R&D.

The R&D capacity in universities and industry, both people and facilities, must be maintained at the leading edge and enhanced to address the complex science, technology, and policy issues involved with sustainability.

Strategy Seven: Develop the workforce talent pool to support the sustainable systems industry.

Workforce development starts with grade school and continues into professional life. Building on plans developed for the other platforms, Arizona must have actions that explicitly address the sustainable systems career opportunities.

ACTION PLANS

As shown in Table 18, the seven proposed strategies have 24 associated actions, all of which need to be set in motion in a phased manner during the first five years to achieve program goals by year 10.

Table 18: Sustainable Systems Strategies, Actions, and Time Frames

Strategy	Action	Time Frame
Strategy One **Make Arizona the "Water Management Capital" of the world**	1. Create the Arizona Water Sustainability Consortium between UA, ASU, and NAU.	Year 1
	2. Develop a partnership with New Mexico and Los Alamos National Laboratory to further their ZeroNet Water-Energy Initiative.	Develop over 1 to 5 years
	3. Launch several "signature" water demonstration projects to both enhance Arizona's image as a sustainable state and qualify products and systems for global market penetration. Focus initially on wastewater cleanup and desalination.	Phase in over 1- to 3-year period; complete by year 10
	4. Develop a water policy framework that will be a model for arid lands sustainability throughout the world. Engage all stakeholders.	Immediate—1-year goal

Table 18: Sustainable Systems Strategies, Actions, and Time Frames (continued)

Strategy	Action	Time Frame
Strategy Two **Harness the sun for power, fuel, food, and medicine**	1. Form a Solar Center for education, research, and outreach, integrating relevant programs in the three universities, the utilities, and industry.	Year 1
	2. Develop and implement signature demonstrations	
	• Renewable energy, focusing on IPP solar power installations	• 1 to 5 years
	• Energy efficiency in buildings and power plants	• 1 to 3 years
	• Bioproducts, including those derived from sea asparagus, plant-based medicines, and edible vaccines	• 3 to 5 years
	• Sustainable agriculture, focused on greenhouse-grown crops and bioproducts	• 2 to 3 years
	• Sustainable forest products, involving a broad platform ranging from biomass energy and fuels to construction materials.	• 1 to 4 years
	3. Develop a set of supportive policies and incentives that will grow the solar-based industry and measure progress	Immediate—1-year goal
Strategy Three **Make Arizona a sustainable manufacturing "Center of Excellence"**	1. Evolve to a ZDM state—zero discharge manufacturing—by transferring the best practices from the semiconductor industry cluster	5-year plan
	2. Develop and implement signature demonstrations	Phase in over 2 to 3 years; complete by year 5
	• Identify semiconductor and/or biotech manufacturing plant for demonstration of new technologies for complete water recycle.	
	• Develop a "green products" industry based on recyclable and/or natural materials.	
	3. Create a Product Development Center to develop and "showcase" sustainable products.	Implement over 2 years

Table 18: Sustainable Systems Strategies, Actions, and Time Frames (continued)

Strategy	Action	Time Frame
Strategy Four **Establish a national and international image for Arizona as the "arid lands livability" state**	1. Appoint a state "Sustainability Czar," reporting to the Governor, and the Sustainability Council, composed of thought leaders.	Immediate
	2. Create a statewide sustainable systems industry association, based on ETIC.	Transition over first two years
	3. Undertake an educational and marketing campaign to increase Arizona residents' knowledge and understanding of sustainable practices.	Develop in year 1, implement year 2
	4. Create a "Blue Ribbon" Panel to assess all current state and local standards, codes, and regulations pertaining to energy, water, environment, land use, and construction and to make recommendations on changes.	Immediate—1-year goal
	5. Market Arizona as a prime location for companies manufacturing/servicing sustainable systems, and develop the *"arid lands livability"* label.	Immediate Develop 5-year plan
Strategy Five **Create the business infrastructure for a sustainable systems industry to flourish.**	1. Implement the recommendations of the Governor's Council on Innovation and Technology (GCIT) to institutionalize the "T+3M" model for new sustainable business creation.	1- to 3-year plan phase in
	2. Create several strategically located product development centers, focused on the three segments—water, solar, and sustainable manufacturing.	3- to 5-year phase in; use existing buildings as far as possible, co-located with universities or industry
	3. Develop eco-industrial parks around sustainable industries, e.g., green construction materials, high-value bioproducts, sustainable agriculture and forest-based industries, and sustainable manufacturing.	3- to 5-year phase in; use existing development plans
	4. Attract funding from nontraditional funding sources such as private family funds, international development banks, etc.	2-year phase in with tribal demos
Strategy Six **Sustain and grow university and industry R&D**	1. Create a statewide Sustainable Systems Science and Technology (S^3T) Collaboratory that networks scientists and engineers across the state.	Immediate. Pilot for water and solar; phase in rest over time

Table 18: Sustainable Systems Strategies, Actions, and Time Frames (continued)

Strategy	Action	Time Frame
Strategy Seven **Develop the workforce talent pool to support the sustainable systems industry**	1. Develop a statewide workforce education strategy for sustainable industry across the state.	Immediate; integrate with other similar recommendations
	2. Increase Arizona's higher education capacity to "grow its own" skilled workers in sustainable systems.	5-year plan
	3. Increase the number of students aware of and prepared to enter science and technology fields (particularly those aimed at sustainable development).	5-year plan
	4. Increase the number of teachers who are competent in the use and application of technology in the classroom.	5-year plan

Strategy One. Make Arizona the "Water Management Capital" of the world.

Water management in arid/semiarid lands is a critical need. Arizona must establish itself as a leader in deploying the latest science and technology that ensures water conservation and optimal use in residential, industrial, and agricultural applications.

Action 1: Create the Arizona Water Sustainability Consortium

The UA, in collaboration with ASU and NAU, proposes a new Arizona Water Sustainability Consortium. The Consortium would integrate four centers currently on the UA campus (the Center for Sustainability of semi-Arid Hydrology and Riparian Areas [SAHRA], the Water Resources Research Center [WRRC], the Water Quality Center, and the Engineering Research Center for Environmentally Benign Semiconductor Manufacturing [ERC]) into a partnership with related ASU and NAU programs and the public and private sectors in the state. An additional key player in this Consortium will be the U.S. Geological Survey (USGS), which has a significant presence on the UA campus and will be bringing another 70 professionals onto the campus in the next few years.

Arizona Water Sustainability Consortium

- Three-University collaboration with USGS
- A statewide Collaboratory
- Includes a Product Development Center
- Strong technology transfer program
- Industry involvement

This "Collaboratory" (see Strategy Six for Collaboratory characteristics) would institute new research, education, and training programs that focus on developing issue-driven water policy options and decision support in a sustainable context, along with developing new technologies specialized for use in arid environments. The structure should minimize the boundaries between academia, industry, and other decision makers. An expanded water policy curriculum should be combined with a focus on key technologies related to reuse, salinity management, riparian protection, climate and drought management, advanced hydroponics, irrigation, and other areas of concern in arid areas worldwide.

The centerpiece of the Consortium could be a **Product Development Center** that brings together university, industry, and government entities to translate research innovation into practical products and services and to direct the research agenda toward areas of interest to stakeholders. (See Strategy Five for Product Development Center characteristics.) This Center could provide the key interface between Arizona stakeholders and university research, through a Web-based hydrologic data system (potentially supported by USGS and connected to ASU and NAU) and a staff of research assistants and applications support experts, who can ensure prompt and efficient communication and "one-stop shopping" that provides some tailored services for particular stakeholders.

Roles of the Four Water Centers at the UA

The UA has extensive and internationally recognized expertise in water-related research, sustainability planning, and technology development. Its diverse water resources academic programs are likewise well recognized. The Center for Sustainability of semi-Arid Hydrology and Riparian Areas is an NSF Science and Technology Center. SAHRA's focus is sustainable management of water resources through stakeholder-driven interdisciplinary research; this mission is directly related to that of the Consortium. SAHRA, already a consortium of 16 U.S. universities, is active in multiple arid regions in the world and has research foci relating to riparian ecosystems, domestic water use and reuse, and water banking that could feed directly into the applications center.

The UA has supported a Water Resources Research Center since 1957. Following the Water Resources Research Act of 1964, the WRRC became the designated center in Arizona for distributing federal funds. Currently, it is focused on outreach and education and providing expertise on state and regional water management and policy. The WRRC could lead the development of the collaborative water policy forum and associated curriculum materials for the three Universities, focused on issues of current concern to Arizona, the Southwest, and other arid regions of the world.

The Water Quality Center is an excellent example of a public-private-academic partnership; it incorporates NSF funding into an industry-supported, international environmental research laboratory that can be used as the foundation of a much broader integrated approach. It is focused on research related to groundwater and surface water quality, including public health aspects.

The UA Engineering Research Center for Environmentally Benign Semiconductor Manufacturing is a multi-university NSF-funded center. It focuses on water treatment technology for high-tech industries in environmental protection, providing innovative leadership that can be a core function of the proposed Consortium. The ERC has mature relationships with manufacturers in the Phoenix area and with ASU, which will assist with integration activities and various education and outreach programs (see Strategy Three for more details).

The Roles of ASU and NAU

ASU has developed key water-related expertise in riparian ecosystem ecology and urban water policy that will be crucial to the development of the Arizona Water Sustainability

Consortium. The recently established ASU Consortium for the Study of Rapidly Urbanizing Regions is focusing on water issues associated with the greater Phoenix area. In addition, the focus of NAU's Center for Sustainable Environments on the ecology of drought and forestry could be further developed in support of the broad collaboratory concept.

Resource Needs and Sources

Proposition 301 funded the Technology and Research Initiative Fund, which has provided funds to enhance the water research, education and outreach programs at the UA. This has provided a jump-start for the proposed Arizona Water Sustainability Consortium.

As part of its long-range plans, UA water research leadership has proposed a new building, the Environmental and Natural Resource Building, which will house the Tucson component of the Consortium, among other programs. This building will be needed no later than 2006. Therefore, Battelle recommends that it be made a priority in the university building plan and that an engineering design study be started early in 2004. ASU and NAU components of the Consortium will be housed in existing facilities.

Additional funds to support current and new faculty and researchers at all three locations, Tucson, Phoenix/Tempe, and Flagstaff, will be obtained through a combination of new federal grants, private and corporate foundations, international grants and contracts, industry memberships, license royalties, and consulting. Battelle recommends a research budget goal of $5 million to $10 million per year.

Industry engagement will be critical to the success of the Consortium and the Center. Access to such a capability, with its expert staff and facilities, also should be a good recruiting tool to attract water-based companies into Arizona. Therefore, Battelle supports the recommendations of the GCIT to continue the state's R&D tax credit, due to end this year, and to encourage corporations to sponsor research at state universities. It is hoped that the emerging area of sustainable systems will be targeted for special consideration.

Time Frame

The Consortium should be established through an MOU between the partnering groups early in 2004. The MOU should call for joint development of a 5-year growth plan that includes program focus areas, faculty hires (at least 12 at UA and four each at ASU and NAU) and facility and equipment upgrades. Collaboratory software that links the groups together in real time and enables joint use of equipment and databases should be installed during the year. Teams should be assembled immediately to prepare joint proposals for expanded funding in key R&D areas. Late in 2004, a decision should be made on the location of the first Product Development Center so that industry partner recruiting can begin in earnest. An Industry Affiliates Program should be in place during 2005.

Action 2: Develop a partnership with New Mexico and Los Alamos National Laboratory to further their ZeroNet Water-Energy Initiative

To advance the goal of sustainable development in the area of energy and water efficiency, Arizona could propose a partnership with a new initiative underway in New

Mexico: the ZeroNet Water-Energy Initiative. Such a partnership could leverage federal laboratory resources and address regional, rather than just statewide, water management technology needs. Development and conservation of Arizona's water and energy resources likely could be achieved more efficiently and more rapidly through a focused collaborative research effort and subsequent implementation. Battelle recommends that the Governor charge a small team to assess this opportunity immediately, as a basis for an early meeting of the Governors of Arizona and New Mexico and development of an MOU.

The Project

The 2002 water crisis in New Mexico prompted a much-needed collaboration among the State of New Mexico, the Electric Power Research Institute, the New Mexico Public Service Company, and the Los Alamos National Laboratory, which has been dubbed the ***ZeroNet Water-Energy Initiative (ZeroNet).*** Its goals are to create new electric power capacity in New Mexico with "zero-net" freshwater withdrawals by 2010; ensure a stable water resource for energy producers; reduce the cost of providing clean, affordable water for energy needs; provide technological solutions and technology information to the public and policymakers; provide technology commercialization opportunities; and serve as a new and innovative model to help other states achieve sustainable energy production while preserving freshwater resources. ZeroNet has become an integrated work plan for the power sector, focusing on such elements as degraded water use, integrated modeling and management, scenario assessment, efficiency, conservation, renewable energy, monitoring, advanced cooling, land management, and education and public outreach.

A potential Arizona partnership with ZeroNet, were it to engage in activities of similar scale, would produce several benefits: securing supplies of fresh water for energy generation; reducing energy and water usage; improving awareness of water issues at all levels of use; and facilitating new technology development and creating new technology business start-ups. Arizona also could draw on an established panel of specialists and use the leveraging potential of the ZeroNet initiative to facilitate funding of its own projects. Moreover, participating in the initiative might catalyze the expertise and experience of the Arizona's water management sector by bringing together business, government, and educational institutions to advance a common goal.

ZeroNet also would benefit by adding a major regional partner, by broadening access to funding, infusing new scientific capacity, adding test and demonstration sites, and increasing potential political support for the initiative's plans.

Resource Needs and Sources

The ZeroNet initiative received $1.5 million for FY2004 from the DOE to support the public/private partnership. At this programmatic scale, an Arizona partnership may require approximately $1 million per year.

Time Frame

The anticipated date for creating new power capacity in New Mexico with zero-net freshwater withdrawals is 2010. Given a later start for Arizona and the need to formulate

an engagement strategy, a reasonable time frame for establishing a ZeroNet partnership might be 2005, with full realization of key benefits targeted no later than 2015.

Action 3: Launch several "signature" water demonstration projects to both enhance Arizona's image as a sustainable state and qualify products and systems for global market penetration

The following are candidate ***signature*** demonstration projects, proposed by Arizona's experts, which will enhance Arizona's reputation in this arena as well as qualify technologies for major new market opportunities (additional details are provided in Appendix C).

Wastewater Reclamation Demonstration: The Nogales International Wastewater Treatment Plant (NIWWTP)

The Project

A plan for handling wastewater in the City of Nogales is being developed because the current plant failed to meet applicable water quality standards and aquifer protection regulations. The project is international as wastewater originates (and reclaimed water could be used) on both sides of the U.S.-Mexico border.

The NIWWTP project presents a near-ideal opportunity as a signature sustainable systems demonstration site. The problems and conditions faced by the project epitomize those faced in creating sustainable water supplies in an arid region and, more generally, in creating sustainable livability in an arid environment. Because the project straddles the border, the challenges and opportunities posed by international relations are inherently interwoven into all design strategies. The city is particularly enthusiastic and open-minded about the opportunities for investigating and implementing sustainable water and energy technologies in conjunction with the NIWWTP upgrade. Land availability is not an issue because the NIWWTP occupies a site much larger than required for the physical plant to achieve compliance. Key government, engineering, and academic groups are collaborating on the NIWWTP; their participation would be enlisted for demonstration plant efforts. Most effluent water from the NIWWTP is not earmarked for a particular use, thus allowing creative identification, treatment, and testing for the highest beneficial reclamation purpose. Finally, the city is consulting with NREL to implement solar power generation on the site, thus addressing objectives of water sustainability and renewable energy in a single demonstration project. Interestingly, the NIWWTP site is in a region receiving the highest annual usable level of solar radiation in the world, based on NREL surveys.

Demonstration of new approaches for metal/metalloid impurity removal from the water, new biomembrane technologies, and energy sustainability could be implemented at the NIWWTP as tertiary add-ons or via takeoff loop adjuncts to the primary and secondary unit operations without jeopardizing compliance performance, design and construction scheduling, or operational ease.

It is envisaged that an NIWWTP demonstration project could become the initial and critical component in a Nogales Eco-Industrial Park (EIP) utilizing the water and energy produced at the site, the readily available land, and the city's receptivity to innovative

development. In turn, the EIP would facilitate and accelerate commercialization of technologies from the NIWWTP demonstration.

Resource Needs and Sources

Funding has been secured for upgrading the NIWWTP and international outfall interceptor to bring them into compliance. However, funding for technology demonstrations would need to be secured separately. Possible sources include NADB, EPA, and DOE. It is expected that demonstration site implementation and development would proceed in parallel with and continue beyond the upgrade work currently underway, without detracting from its pace or optimum configuration and operation, yet providing value added to the NIWWTP in the long run.

A steering committee would be established to administer and expand on a demonstration of water sustainability at the NIWWTP. Suggested members include four university experts on sustainable water engineering; two experts on technology transfer; a representative from the proposed Arizona Water Sustainability Consortium (see above); two experts on renewable energy (including one from NREL); two representatives from water product industries; and representatives from the Arizona Department of Environmental Quality, the EPA, the International Boundary and Water Commission, the Border Environment Cooperation Commission (BECC), the City of Nogales, and the Arizona Department of Commerce.

Time Frame

The design parameters and criteria that will constitute a request for proposals from design engineers are currently being developed by a technical committee led by the Arizona Department of Environmental Quality, with representatives from the EPA, the International Boundary and Water Commission, BECC, the UA, and the City of Nogales. The upgraded plant should be in operation by 2005, and demonstrations of new technologies could start in 2006.

Desalination Demonstration #1: Deluge AzMex High Quality Drinking Water Project

The Project

The technology exists to “desalinate” saltwater; but, the operating expenses, mainly the electricity expense to run the high-pressure pumps, are so high that it does not make economic sense. If costs can be lowered, Mexico and Arizona could access an unlimited supply of water from the Gulf of California.

Deluge, Inc., is proposing that its new technology, the thermal hydraulic engine, can reduce the cost of desalination by 50 to 75 percent. The Deluge desalination testing will begin in coordination with the U.S. Department of Interior’s Bureau of Reclamation laboratory in Yuma, Arizona. This Yuma facility houses the largest desalination system in the United States and is home to the Water Quality Improvement Center (WQIC). Besides desalinating, the new Deluge engine can pump the water from the Gulf of California to Yuma, and then to the Central Arizona Project (CAP) that supplies water to Phoenix and Tucson.

The scope of the first test at Yuma will provide "proof of concept," a necessary step toward building a pilot plant. A Cooperative Research and Development Agreement (CRADA) will be developed between Deluge and the WQIC for this testing phase.

Signature Water Demonstrations

- Wastewater reclamation at Nogales plant
- Deluge AzMex High Quality Drinking Water Project
- DEWVAPORATION technology demonstration

For the full pilot plant, a pipeline must be built from the gulf to Yuma. A pump will be installed in Mexico to supply ocean water to the Yuma facility. An international pipeline permit and easement will be a challenge, but water supply projects will be a necessary part of the future of Arizona and Mexico. Another pipeline will be needed from Yuma north to the CAP (about 100 miles). Permitting and coordination with CAP will be challenging again, but the water quality of the CAP will improve with the new desalinated water supply.

An interesting aspect of the pilot plant is that it can be solar powered. Deluge's new technology is an engine that runs on hot water. This hot water "fuel" can come from hot-water solar panels, similar to rooftop systems that provide hot water for home use. The hot water also can be produced from waste heat from power plants as a less expensive source of "fuel." The Arizona Public Service Yucca Power Plant is located across from the Yuma Desalination Plant and could be brought into this demonstration.

Desalination requires high-pressure saltwater. A large pump is required to pressurize the saltwater and push it through the reverse osmosis membranes (basically very dense filters). The Deluge technology can produce the high-pressure saltwater at a much lower cost because it uses a new way of producing mechanical power.

Resource Needs and Sources

Sources of funding will be studied in Phase 1. Battelle expects the project to be owned ultimately by a new publicly traded corporation that will duplicate the project in many areas of the world. The new corporation will be formed and initially owned privately by a consortium of large corporations and private investors. The Deluge technology will be licensed to the new corporation. Funding for Phases 1 and 2 could come from a variety of sources, including grants from the DOE, USDA, and the Departments of the Interior and Homeland Security (DHS). Industrial development bonds may be used for Phase 2. An initial public offering, rural industrial bond issue, and strategic bank financing will provide funding for Phase 3 and for multiple projects in the United States and abroad. Funding from Mexico may be available for the saltwater pipeline from the Gulf of California to Yuma.

The costs for the project are estimated as follows:

Phase 0—Proof of concept—$30,000–$50,000 (paid by Deluge, Inc.)

Phase 1—Scale-model plant—$2 million

Phase 2—Pilot plant with 10-inch pipeline—$150 million

Phase 3—Processing plant with 100-inch pipeline—$1.5 billion.

Time Frame

The Phase 1 model could be in operation by 2005. The Phase 2 pilot plant could be built by 2010, with Phase 3, a full-scale expandable system, built by 2020.

Desalination Demonstration #2: Pilot Plant Demonstration of the DEWVAPORATION Technology for Water Reclamation from SRP's Coronado Generating Station Pond

A number of technologies are being considered to improve the efficiency and cost of desalination as part of Phase 2 of the CASS (see Section 2). By way of example, this study proposes using a new development from ASU.

The Project

Currently, at the Coronado Generating Station, about 300 gallons per minute of saline water flow to the evaporation pond for disposal. This water can be reclaimed by the DEWVAPORATION technique and returned to the power plant for reuse. It is proposed that a 1,000-gallon-per-day pilot plant be built at ASU and transported to the Coronado Generating Station for dedicated field reclamation of saline waters fed to the evaporation pond, as a demonstration of this technology. The pond water contains suspended soils and dissolved corrosive salts, which make its economic reclamation difficult to impossible by standard membrane and boiling techniques. The DEWVAPORATION towers are made of thin, noncorrosive plastics and operate at atmospheric pressure. Steam or waste heat can be used as an energy source. The applications are extremely broad in that volatile trichloroethylene and MTBE can be removed separately from nonvolatile nitrates, arsenates, and salts in an economical manner.

Resource Needs and Sources

If approved, the Salt River Project would pay for this project.

Time Frame

To be determined.

Action 4: Develop a water policy framework that will be a model for arid lands sustainability throughout the world

The State of Arizona is challenged in the area of water policy. Among the issues being addressed are the following:

- Regulation of well drilling; lack of local or multijurisdictional authority to regulate development based on sustainable water supplies
- Groundwater recharge and inadequate protection of groundwater resources and natural assets (e.g., wetlands) that rely on groundwater
- Pressure to develop protected irrigation non-expansion areas
- Subsidized pricing.

To become the "Water Management Capital" of the world, Arizona must demonstrate exemplary and innovative policy approaches to the sustainable development and use of

water resources. Examples are available from other arid and nonarid areas where sustainable water management has become an important policy issue (Tables 19 and 20).

Table 19: Examples of Sustainable Water Policies

Source	Policies
European Union: 2000 Water Framework Directive	• Combines ecological protection with long-term water use and sustainable development • Implements projects in five countries
Canada: Federal Water Policy	Specifies five key strategies: • Water pricing • Science leadership • Integrated planning • Legislation • Public awareness
Canadian federal water policy complemented by more specific policies/regulations at a provincial level	• Alberta is reviewing uses that remove water from the water cycle as part of a *Water for Life* sustainability strategy
Australia, a leader in water industry reform	• Full-cost recovery water pricing and water trading led to expansion of high-value crops • Separation of land and water rights promotes agricultural water-use efficiency

Table 20: Relationships of Water Policies to Water Technology Demand

Source	Policies
EU	Eco-labeling of dishwashers and washing machines
Cyprus	Government incentives to farmers for adoption of micro-irrigation systems
Denmark	Policy commitment to reduce water demands led to increased use of water-saving devices
Spain	Policy goal of saving 1 million cubic meters of water per year spurred market for water-saving appliances and new water meters

Recommendations for a Water Policy Framework

Battelle proposes that Arizona's water policy framework activities comprise the following:

Establish a broad-based Policy Forum to identify options for riparian protection, water markets for particular contexts, urban water issues, drought management, etc.

Adopt a proactive water policy development and review process that addresses the long-term vision of sustainable development:

- Induce a sustainable systems economic development cluster
- Enhance and foster a statewide business climate that embraces sustainability.

Adopt best policy practices, including performance-based and incentive approaches, tailored to Arizona's needs:

- Set performance standards for the water industry (the Environmental Portfolio Standards for energy may well be a model)
- Promote economic instruments such as life-cycle costing for new technology introduction, taxation on excessive water use, and financial incentives for water conservation and introducing water-efficient technologies.

Create a Sustainable Water Policy Working Group, including key government, tribal, industry, and NGO stakeholders, to monitor implementation of policies.

Resource Needs and Sources

The Water Policy Working Group and Policy Forum will require staff support, obtained from the university expert base and the cognizant state departments. A rough cost estimate for this effort would be $100,000 to $200,000 per year from the state Water Department.

Time Frame

This is a critical issue for Arizona's future economic growth and quality of life, and work should begin immediately. The Governor has appointed a Water Czar to address the drought issues; but, a framework such as Battelle has proposed is needed for the long term. The ability of Arizona water technology entrepreneurs to both develop and market their products effectively will be shaped by whether Arizona is perceived as a model of sustainable water management.

Strategy Two: Harness the sun for power, fuel, food, and medicine.

With such places in Arizona as "the Valley of the Sun," it is not surprising that the sun is thought of as both an environmental and economic resource for the state. There is a huge solar resource in the state; but, unfortunately, there are limited amounts of other types of renewable energy resources. Arizona should, therefore, focus on developing this significant resource, as a means of differentiation in the renewable energy arena.

Typically deployed as small-scale thermal or PV systems, solar technologies recently have been applied in larger-scale projects. In Arizona, for example, there are two central plant style PV installations. Further, there soon will be a 1-MW concentrating solar power plant. Solar thermal in building applications has, however, been limited to smaller-scale projects except for solar hot water. With today's technology, this can be expanded to include solar heating and cooling.

This strategy will broaden the definition of solar beyond electric power and building applications to include solar-derived products such as fuels, bioproducts, agriculture, and forest-based products. All result from harnessing the sun through the process of photosynthesis.

Action 1: Form a Solar Center for education, research, and outreach, integrating relevant programs in the three universities, the utilities, and industry

Dr. Mike Pasqualetti, Chairman of the Governor's Solar Council, has proposed forming a nonprofit, independent center concentrating on the development and use of solar energy

(anywhere, but focused on Arizona). The Solar Center's charter would be to coordinate and consolidate disparate solar programs in the state, provide an unbiased source for solar information, and facilitate activities that expand the understanding of solar energy as an increased component of the fuel mix. A Solar Product Development Center also could be part of this effort.

As envisaged, the Center would house capabilities for outreach and education, policy and economic analysis, and research and testing.

Similar to the Water Consortium, the Solar Center would utilize collaboratory software and systems to network with the research and education programs at the UA, NAU, and ASU and with the development work at the STAR center owned by the APS.

It also is recommended that MOUs be arranged with NREL in Colorado and Sandia National Laboratory in New Mexico to facilitate information sharing and possible joint staff appointments and R&D projects that will bring innovative solar technologies to Arizona. Such linkages could give the appearance that Arizona has a national laboratory within its borders, and would enhance access to federal funding in this area.

Arizona Solar Center

- Coordinate and consolidate solar programs in the state
- Nonprofit, independent center
- Focus on education, R&D, and outreach
- Operate as a collaboratory
- MOUs with NREL and Sandia

Resource Needs and Sources

Based on similar centers, Battelle recommends a budget of $5 million to $7 million per year. An existing facility on the ASU campus will be the first home of the Center; but, other nodes are anticipated in Tucson and Flagstaff by 2005.

Operating costs will be for center management and support staff, education and outreach programs, and operation of the Solar Product Development Center. R&D, testing, and productization activities will be funded through a combination of federal grants (e.g., DOE, NSF, and the Department of Defense [DoD]) and industry support.

Time Frame

Detailed planning of the Solar Center should start in earnest in 2004. Initially, agreements would be made with Arizona-based institutions to join the Center and be members of the Collaboratory. A set of operating principles should be developed early in the year for members to approve. The Center is expected to be in full operation in the second half of 2005. In parallel, overtures will be made to NREL and Sandia to form alliances via MOUs.

Action 2: Develop and implement *signature* demonstrations

The following are candidate *signature* demonstration projects that will enhance Arizona's reputation in solar-based technologies, as well as qualifying them for major new market opportunities. This is a very active and rich area, with many possible demonstration projects on the drawing board or in early stages of development. Examples include new solar electric power plants; solar-derived fuels; solar-driven energy efficiency

improvements in buildings and power plants; and solar-based biotech, agriculture, and forest products (additional details are provided in Appendix C).

Renewable Energy and Fuels

These demonstration proposals represent near-, mid-, and long-term energy options for solar and hydrogen for the state.

Demonstration: Develop and Implement Large Solar Power Plant Demonstrations

Four viable concepts are proposed for large solar plants to be built by independent power producers (IPPs), in addition to the planned solar power expansion by the three large utilities, noted in Section 2. Battelle believes that encouraging IPPs to build and operate solar plants in the state will benefit the state's economy because they are more likely to manufacture components in Arizona.

The Concepts

1. A 500- to 1,000-MW centralized hybrid system (parabolic solar trough concentrators plus natural gas) installed by Solel Solar Systems, Ltd. (owner/operator of a 354-MW solar installation near Barstow, California). Solar trough technology has been proven in the field for more than 20 years. Nine central power plants totaling 354 MW have used this technology since 1984, accumulating 110 operating years and producing about 7.5 million kWh of electricity in Southern California. It is proven to be the lowest cost solar power, and technological improvements have made plants up to 20 percent more efficient today than 20 years ago. A cluster of five 100-MW plants, built in Arizona over the next 10 years, will lower the electricity price to 7 to 10 cents per kWh.
2. 1-MW distributed PV installations on Indian lands in cooperation with the Inter Tribal Council of Arizona. Arizona urgently needs solar plants, either on or off grid, sited on reservations, preferably with components manufactured in state so that it can assign the "Tested and Qualified in Arizona" label for exports to other arid lands (see Strategy Five).
3. 1-MW centralized PV installation at Sky Harbor Airport. This system would serve the dual purpose of making the airport self sufficient and introducing Arizona's solar industry to the thousands of people who pass through the airport each year. It would provide a location for Arizona-based companies to showcase their solar products and a cost-effective means to educate citizens and visitors on the advantages of renewable energy.

Potential Solar Power and Fuel Signature Demonstrations

- A 500- to 1,000-MW centralized hybrid solar system
- 1-MW distributed PV installations on Indian lands
- 1-MW centralized PV installation at Sky Harbor Airport
- A solar/hydrogen subdivision in the Valley
- Arizona (hydrogen fuels) HyWays

4. Solar/hydrogen subdivision—in cooperation with Del E. Webb School of Construction, ASU, and the American Hydrogen Association. Looking to the future, and a hydrogen economy, Battelle recommends preliminary planning for a

solar/hydrogen system that will provide all the power, heating/cooling, hot water, and fuel needs for a new housing development in the Valley. This concept links very well to the "Ultimate" Sustainable Home described below.

Resource Needs and Sources

The key to success will be to provide an incentive package that will induce IPPs to take the risk of building power plants in Arizona. Long-term "green" power contracts, both in and out of state, will be necessary for IPPs to obtain the necessary private financing. The tribes will need state assistance to secure long-term power contracts. A Green Credit bank, which the Western states are considering, should provide an additional inducement. State support in plant location and obtaining the necessary permits etc. also will be needed.

Time Frame

Arizona should consider a plan to engage IPPs as soon as possible and phase in on- and off-grid plants over the next 5 years. Battelle believes that IPPs will be essential for the state to build an indigenous solar manufacturing industry.

Demonstration: Hydrogen Fuels—Arizona HyWays

The Project

In a proposal from Roy McAlister, American Hydrogen Association (AHA), renewable hydrogen and/or methane would be transported from farms, forest slash accumulation areas, and other generation sites to market by way of "HyWays." In many instances, these would be state and national highways and/or roadways that become HyWays by adding renewable energy pipelines below them.

HyWay pipelines transporting methane would co-deliver carbon for producing high-value goods. New technology would be incorporated in mass-produced components that allow existing engines in Arizona's on- and off-road fleets to be converted to hydrogen and/or various blends of hydrogen and methane called Hy-Boost fuels.

Industrial parks along these HyWays would include plants to process renewable methane into carbon products and hydrogen. Service stations would safely, quickly, and efficiently fill vehicles along HyWays from modular distribution units that offer hydrogen and Hy-Boost fuels.

The initial phase of this project could be started with a HyWay pipeline that brings methane from dairies to industrial parks around Phoenix and Tucson. Hydrogen would be sent to distributed energy and transportation applications from the industrial parks.

Resource Needs and Sources

Financing the improvement of highways to HyWays for distribution of hydrogen could come from the federal Highway Trust Fund and the DOE's FreedomCAR and Hydrogen Fuel Initiative.

Time Frame

DOE has issued a request for proposal for hydrogen storage and distribution projects, and several regional consortia have responded. It is recommended that Arizona prepare for the next solicitation, in 2004, and have AHA-Arizona lead a consortia to submit the HyWays initiative.

Energy Efficiency Improvements

Arizona has established itself as a state that values energy efficient homes and buildings; but, the state has more potential for improvement, as was indicated in the SWEEP report described in Section 2. Battelle's proposal is to use carefully targeted demonstration projects to build energy efficiency into a "whole product" offering for new business creation and expansion. The approach is to

- Create vertically integrated consortia (involving architects; builders; and suppliers of green materials, energy efficient systems, and renewable power and water systems) and bid as teams on new construction products—residential "smart houses," schools, and commercial and industrial buildings.
- Identify two to three large projects (e.g., a school campus, state and city buildings, or military housing) as signature projects.
- Build several "inherently sustainable buildings" that will serve their function, but also be living laboratories for sustainable practices and a showcase for Arizona's emerging sustainable systems industry.
- Take advantage of the potential for utilizing solar air conditioning.
- Require green materials for construction, complete water recycle and reuse, and PV solar electric power production.

The following three early-stage projects can demonstrate advanced approaches to total building energy conservation.

Demonstration #1: Gila Bend Unified School District Sustainable Campus

The Project

Redevelopment of the entire K–12 campus involves three schools: elementary, middle, and high school. In his plan, Paul Winslow, a leading sustainability advocate and architect, proposes that the buildings

- Utilize solar thermal energy to drive absorption chillers and provide heating through a pipe and fan coil system.
- Integrate PV panels to minimize power from the grid.
- Utilize natural daylight lighting systems in all occupied spaces, particularly those used for educational purposes.
- Adopt smaller-scale strategies, such as motion sensor lighting controls and waterless urinals.

- Harvest water for irrigation purposes.
- Recycle construction waste.

Resource Needs and Sources

Financing will come from school bonds. School board support will be required to accept higher up-front costs of solar and other energy efficient systems, with the expectations of lower downstream operating and maintenance costs (i.e., use a life-cycle cost analysis as the basis for procurement decisions).

Time Frame

The final design will be completed in 2004, and construction is projected to begin in 2005. However, the development is contingent on a school bond being passed in late 2004.

Demonstration #2: The "Ultimate" Sustainable Home

The Project

Sustainable Engineering LLC (Brian Beaulieu) is building a new house in the Troon community that will be a model for sustainability, going well beyond any known Green Building Guidelines. This sustainable design is driven by health concerns arising from traditional construction materials and building methods, heating/cooling systems, and power sources. Initially at least, the target is high-end homes, whose owners want a healthy living environment. This 6,000-square-foot home will comprise several linked cast-concrete structures, using no wood, no paint, and only water-soluble glues. Solar panels will electrolyze water into hydrogen to power a generator set. Low-voltage light-emitting diodes, which eliminate electromagnetic fields, produce no heat, and use 1/10th the power of compact fluorescent lights, will provide lighting. Waste heat will be used to heat water and the pool, and cooling will be provided by a water wall. Solid waste reduction will be achieved through recycle and compaction. Hydrogen also will be used to power vehicles.

Energy Efficiency Signature Demonstrations

- Gila Bend Unified School District Sustainable Campus
- The "Ultimate" Sustainable Home, Scottsdale
- City of Scottsdale Senior Center
- Increase efficiency of Ocotillo Power Plant

The house will be used as a test bed for new sustainable technologies, with a view to creating local industries around them. The goal is to lower the costs to the point where these technologies can be mass produced for low- to medium-cost housing developments.

Resource Needs and Sources

The demonstration home will be privately financed. Technical help is being obtained from East Valley College.

Time Frame

All approvals have been received. Groundbreaking is planned for late 2003, with occupancy expected in late 2004 or early 2005.

Demonstration #3: City of Scottsdale Senior Center

The Project

The McDowell Village in Scottsdale, a new senior living and recreation center, is in the planning phase. The city will own two buildings in the complex, construction of both to start in April 2004, and is currently working with the SRP to obtain PV panels to carry a portion of the lighting load. The city also is working with So Cool Energy Inc. to evaluate the use of a central chiller and solar thermal technology for hot water, space heating, and air conditioning to provide up to *65 percent of the energy* required. So Cool is the exclusive U.S. licensee and partner company of S.O.L.I.D., the Austrian company that developed a solar thermal plus absorber chiller system, which has a solid track record in Europe for operational reliability and cost effectiveness.

Resource Needs and Sources

So Cool will install a turnkey solar plant under an energy performance contract, requiring no initial payment by the customer and guaranteeing a certain level of energy savings (normally 20 percent). So Cool will be responsible for the operation and maintenance of the facility for the life of the contract (normally 25 years) at no additional cost.

Since the initial cost for a chiller system is higher, many planners will not employ them. The solar approach has the commitment of city staff and the Mayor, but the city still must comply with its procurement process. Therefore, even after the decision to use a chiller and solar energy is made, the city must still go through a bidding process. This requires solar companies such as So Cool to participate on the front-end without any guarantee of remuneration. Although many companies face this prospect, the solar industry, in its infancy, needs a different process if solar is to be promoted.

Battelle recommends that Scottsdale take the lead for the state in changing its procurement rules to encourage introduction of solar-based and other energy efficiency systems. Since introduction of such systems requires up-front engineering work, one model would be to hold a prequalification process based on life-cycle costing, leading to a sole source contract for design, engineering, and installation of these systems.

Time Frame

Building starts in April 2004; useful demonstration results are expected in late 2005.

Another aspect of energy efficiency improvements is to seek ways to increase the efficiency of thermal power plants, which currently operate at approximately 40 percent efficiency.

Demonstration #4: Increase Power Plant Efficiency

The Project

It is proposed to use “hot” cooling water (i.e., waste heat) from a power plant to power the Deluge thermal hydraulic engine. Since the engine has a rotating shaft, it can drive auxiliary equipment such as pumps and air handlers or an electric generator. Such work done by the engine increases overall plant efficiency.

The project will proceed in the following incremental phases:

Phase 0: Using available proven technology, a 2-hp engine will be installed at the APS Ocotillo power plant, powered by cooling water waste heat and driving an air handler to demonstrate useful work.

Phase 1: The engine will be scaled up to the 25+-hp range, suitable to drive a cooling water pump or a cooling tower fan. Capital cost is expected to be less than $2.00 per hp. At this cost, the Deluge technology will provide a cost benefit over existing (electric motor) technology for any new installation of cooling water pumps or cooling tower fans.

Phase 2: The engine will be increased further to the 100+-hp range, suitable for driving an electric generator. Capital cost is expected to be less than $1.00 per hp, thus providing electric power at a cost comparable to that of the power plant proper. Virtually all of the thermal power plants worldwide will be candidates for this add-on equipment, which will increase overall plant efficiency and plant capacity.

Phase 3: A large-scale pilot plant will be constructed to provide electricity for 300 to 500 homes. The capital cost is expected to be $0.50 per watt.

Resource Needs and Sources

Funds for the four projects will come from private investment and industry and government grants. The following estimates for the projects include construction and development costs:

Phase 0—Proof of concept—$50,000 to $100,000—paid by Deluge, Inc.

Phase 1—25+ hp—$250,000 to $300,000—paid by Deluge, Inc.

Phase 2—100+ hp—$1 million—paid by Deluge and matching fund grants

Phase 3—2,000-hp pilot plant—$2 million to $3 million—paid by Deluge and matching fund grants.

Time Frame

The proposed schedule to complete projects through Phase 3 is 7 to10 years. However, Phases 0 and 1 could be completed by the end of 2005.

High-Value Bioproducts

Two concepts based on new biotech innovations should be pursued, using either greenhouse hydroponic or field-drip irrigation growing methods or cultivation of salt-infused soils, depending on the area selected. Arizona has experience in universities as well as in the private sector in applying these methods to crop cultivation. The challenge, and opportunity for new business, lies in taking advantage of advances in plant genomics to produce high-value bioproducts. Growing the product in the plant is sometimes referred to as a "green factory," whereas producing the products by processing the plant materials is called a "biorefinery." Arizona needs to look at both prospects, as follows:

- Capitalize on existing university centers of excellence in plant genetics, photosynthesis, and natural products at the UA and ASU.

- Identify two to three opportunities to build a consortium of universities, industry, and private investors around, e.g.,
    - Natural cancer drugs
    - Edible vaccines
    - High-value chemicals.
- Leverage federal programs and private investments in creating two to three signature pilot plants that use either greenhouse or field crop-growing methods.

Demonstration #1: Colorado River Delta "Eco-Park"

The Project

This concept utilizes salt-laden soil for alternative crops that grow in such environments and uses these crops as a "platform" or "biorefinery" for a range of biobased products. Sea asparagus is one such plant because it is a source of oil. One idea for the Colorado River Delta might be to create an "eco-park" that combines sea asparagus farming with shrimp and fish farming in an integrated energy, bioproducts, and food processing economy, supplying jobs to the Yuma-Mexico region. This model could be replicated elsewhere around the world.

As a way to continue field agriculture, several companies are examining the economics of growing crops in soil that is too salty for traditional crops. Since Arizona's soil salinity is increasing in certain areas, it is appropriate to start to plan for such a transition. The experience of the Seawater Forests Initiative of East Africa could be applied in this case. Dr. Lucian Spataro, of UA, is pursuing collaborations with this group for a demonstration in Mexico and has proposed that a sea asparagus demonstration project be sited in Arizona.

Resource Needs and Sources

The first step is a detailed plan and economic analysis to demonstrate to investors that an eco-park of this type would be profitable. Such a project could be sanctioned by CASS and/or the state Department of Commerce at a cost of approximately $250,000. The results would serve as a basis for decisions on demonstration scopes and sites in the state.

Time Frame

To be determined.

Demonstration #2: Develop a Natural Product Drug Industry in Arizona

A collaborative team of researchers from the UA's College of Agriculture and Life Sciences, Arizona Health Sciences Center, and the Arizona Cancer Center are testing natural compounds isolated from desert plants and microorganisms for their anticancer properties, with funding from the Arizona Disease Control Research Commission.

Bioproducts Signature Demonstrations

- Colorado River Delta Eco-Park
- Natural product drug production–cancer
- Edible vaccine production

During the 3-year process, the team tested compounds from more than 500 plant species collected from open areas in the Arizona desert. More recently, work has begun in microbial drug discovery. The process involves numerous steps in progressively extracting and purifying active ingredients from plants and microorganisms. The group has found several compounds that have demonstrated antitumor properties in laboratory tests.

The Project

Battelle proposes a demonstration to apply this new extraction technology to produce natural cancer drugs from various plant species and microbial colonies in sufficient quantities to support clinical trials. If successful, the technology would be licensed for full-scale drug manufacture.

The demonstration project will entail a complex, multistep process that must be scaled up from the current bench-scale system. Key processes include isolating microorganisms, both bacteria and fungi; growing them separately in selective media; isolating pure cultures of the key organisms; and then growing them.

Following these steps, the cultures are extracted with organic solvents. The extracts contain large amounts of secondary metabolites, which are tested in biological assays that use perpetual cancer cell lines for three types of cancers: breast cancer, non-small-cell lung cancer, and central nervous system cancer.

It is expected that partnerships with one or more pharmaceutical companies will be necessary to achieve this goal.

Resource Needs and Sources

Since it takes an average of 10 to 20 years and a minimum investment of $350 million to develop an anticancer drug, this project will be a huge undertaking for the state and will likely require recruiting a major pharmaceutical company to locate a plant in Arizona. The National Cancer Institute is a source of early funding for translational research; later-stage development may attract venture capital if results are favorable.

Time Frame

Research at the UA is in its early stages. The steps have been tested successfully in bench-scale experiments; small quantities of compounds, sufficient for animal testing, have been produced. Assuming success at this level, moving to a bigger-scale operation will take 3 to 5 years and $10 million to $20 million.

Demonstration #3: Develop an Edible Vaccine Industry in Arizona

The Project

It is proposed that greenhouse technology be used to grow edible vaccines for both domestic and global consumption. Dr. Charles Arntzen, of ASU, is internationally recognized for his successful work on the delivery of edible vaccines through food plants such as bananas, potatoes, and tomatoes—a revolutionary innovation that may be of particular importance in developing countries where infectious diseases are a major cause

of death, especially for children, and delivery of standard vaccines is problematic. Recently, this research has been extended to creating effective vaccines against biowarfare agents.

Dr. Arntzen has grown tomatoes that carry a gene from a strain of the *E. coli* bacterium. In reconstituted juice, a protein made by the *E. coli* gene should act as a vaccine, priming the immune system to recognize and fight off the actual bacteria. Tomatoes should be an initial target for this demonstration because greenhouse-grown tomatoes cannot easily pass their altered genes to other crops and tomato-processing equipment is relatively cheap.

Resource Needs and Sources

Test batches of various fruits are being grown in greenhouses on the ASU campus. To scale this project to production size will require several million dollars. The Gates Foundation is an obvious source of funds, given its commitment to third world vaccination programs. In addition, the NIH, acting for the DHS, should be receptive to a demonstration focused on bioterrorism mitigations.

Time Frame

This project should be given priority, considering the concerns about children's health (e.g., recent cholera epidemic) and bioterrorism. Scale-up of production is a critical factor for success.

Sustainable Agriculture

This area should be linked with the foregoing bioproducts opportunities because, in many cases, it could use the same controlled growing technologies.

Demonstration #1: Greenhouse-Based High-Value Crops

The Project

The greenhouse industry is very competitive and should be expanded and enhanced to include products such as phytoremediation plants, organic crops, and natural biobased products, including edible vaccines and drugs. Attributes of greenhouse cultivation include the following:

- Compared with field crops, it uses 1/10th to 1/20th the water. Hydroponic production has become the de facto standard for growing greenhouse vegetables. The methods are very clean, using no organic material. In addition, they give the grower complete control over the crops' nutritional needs, allowing the grower to maximize growth and fruit production.
- No pesticides are used in the process.
- The plants produce carbon dioxide (CO_2), which can be recycled and used as a source of fuel.
- Fresh crops can be grown year-round indoors.

- It provides new business opportunities for local greenhouse manufacturing and for plastics manufacturers who might want to produce polycarbonate siding

Resource Needs and Sources

Expanding the greenhouse crop industry may preserve agriculture in rural areas. However, small growers will need help getting into the "big boxes" (large-scale agribusinesses). A state-supported campaign for locally grown produce in the big boxes would help immensely, perhaps through programs like "Arizona Grown."

Another possibility is to manufacture greenhouses in the state rather than import them from Holland, which is the current practice. The state should undertake an analysis to determine whether this makes economic sense, and, if so, to determine the best approach—recruiting Dutch companies to locate in Arizona or helping local manufacturers to upgrade their capabilities.

Time Frame

The greenhouse industry is flourishing in Arizona, and consideration should be given to immediately expanding it into other areas of the state that meet the growing criteria. This likely will entail incentives for companies currently engaged in the business and a recruiting campaign to bring other companies into the state. Several global marketing opportunities could be supported by the state, particularly targeting Asian markets with specialty products valued in Asian economies.

Sustainable Forest Products

For the forest products industry to be economic, it must operate from a platform that supplies products and services derived from wood to many different markets—energy, construction, agriculture, etc. The following proposals are in different stages of development. Two proposals would capitalize on forest-thinning needs to develop eco-industrial parks, anchored by wood biomass power plants. The third, somewhat speculative, would use advanced technology to produce economically attractive transportation fuels.

Demonstration #1: Combined Wood-Based Power and Product Manufacturing, Central Yavapai County (combines renewable power and sustainable forest products)

The Project

BIOgen Power Group, Prescott, LLC, is developing a renewable energy plant and eco-industrial park for Central Yavapai County. It intends to deliver low-cost fuel for power generation and low-cost raw material for conversion into value-added products. The power plant will generate additional profits through the monetization of green tags, which are certificates representing the environmental attributes associated with generating electricity from renewable technologies.

Potential Signature Wood Biomass Power and Fuel Demonstrations

- 10-MW biomass power plant, Yavapai County
- 3-MW biomass power plant, Eagar
- Wood-chip-to-ethanol pilot plant

The biomass power plant will provide benefits to co-located industries above and beyond electricity. For example, locating next to a plant that generates both waste CO_2 and heat is ideal for a high-tech greenhouse for crops or bioproducts that typically spends between 3 and 10 percent (depending on the price of natural gas) of its operating costs on heat. Both ASU and Yavapai College have initiatives in this area. The BIOgen Power Group expects to deliver many of the inputs these facilities need at a low cost and plans to configure the plant to take advantage of this convergence.

The project will have a 10-MW wood biomass power plant as its base unit. The plant will be located on a site that will accommodate value-added industries that assist in supplying fuel to the biomass plant and use the power generated by the plant. Adjacent value-added industries might include, but are not limited to, wood products and greenhouse agriculture. The biowaste stream from the value-added industries would provide more fuel for the plant. The model is scalable and could be replicated in many communities around the country with fire and beetle kill issues. By utilizing wood from the beetle-infested forest to generate power, the plant will be one of the few users of this waste product.

Partners will include Environmental Forest Solutions, White Mountain Forestry, ASU, Yavapai County, a large power plant developer, various small businesses with an envirotech focus, the Prescott Urban Wildland Interface Commission, Yavapai College, and a green power buyer.

Resource Needs and Sources

Cost to build out the plant and the eco-industrial park is estimated at $30 million to $35 million. More seed funds may be needed to help some of the co-located businesses.

The plant/park will be financed with private capital. However, federal grants (e.g., DOE) will be needed to insert the disruptive technologies. State help is needed to secure the land for this park. Federal help is needed for forest extraction, and this could come from the new money in the Healthy Forests Restoration Act. The plant will generate tradable renewable credits (TRCs); without these TRCs, the project would not be economically viable at this low level of power production. Also, because the plant will be classified green, it will generate carbon emission credits that will be bought by companies with higher emissions of nitrogen and sulfur compounds such as the larger coal-fired power plants.

Help from the state will be required to secure 10-year forest contracts because financing of the plant will be impossible without them. Since about 5 million acres of forest are state owned, this could be a near-term initiative to increase biomass power generation. Also, increasing the state's Renewable Portfolio Standard (RPS), especially as it pertains to biomass, would be useful. Other needs include favorable tax treatment for sustainable industry and help with obtaining federal research grants.

Time Frame

Timing is contingent on obtaining financing, which in turn depends on obtaining the 10-year forest contracts.

Demonstration #2: Bioenergy and Integrated Industry Operations, Eagar, Arizona

In an approach somewhat similar to the previous project, Environmental Forests Solutions, Inc., proposes to centralize a manufacturing industry into a single location to add value to small-diameter wood and burn the waste product in a 3-MW biomass power plant, selling power at a reduced rate to site operations. The park is located at a 7,000-foot elevation near Eagar, Arizona, a town of 3,000 people with an area energy consumption of 26 million kWh of electricity. The town has expressed strong support for the energy project as a means of electrifying the region and creating a micro-grid off the national transmission grid. There is also strong support for the jobs created because the unemployment rate averages above 12 percent.

The Project

When energized in November 2003, this APS facility was the first bioenergy plant in Arizona.

Added-value industry based on small-diameter timber provides the economic engine that benefits the region. The USFS has announced a stewardship concept for thinning the 2 million acres of the Apache-Sitgreaves National Forest, part of a 400-mile stand of ponderosa pine, the largest in the world. The present plan calls for thinning 15,000 acres per year, which is the least amount viable for a single-industry park. This would yield approximately 12 tons per acre of waste wood material, providing saw timber and waste wood to fuel the power plant.

Use of this prototype opens the door for a variety of industrial applications that use wood fiber or by-products to create value-added materials. Among the potential applications that Battelle recommends for an eco-industrial park are the following:

- Biofuels based on wood chip, including biodiesel and ethanol (see below)
- Pellet fuels, molded from waste wood, used in commercial boilers and direct heat sources
- Greenhouse operations, using waste CO_2 from energy production, growing vegetables, small trees, and a variety of other green products, including biomass fuel
- Waste heat from energy production captured in industrial processes at very low cost to the producer
- Building materials, such as oriented strand board, moldings, lumber, extruded panels with concrete blends of fly ash, and related natural wood products
- Sod and soil additive operations based on lumber and bark residues.

Resource Needs and Sources

Similar to the Yavapai demonstration.

Time Frame

Similar to the Yavapai demonstration.

Demonstration # 3: A Wood-Chip-to-Ethanol Pilot Plant

This demonstration would further the national effort to develop lignocellulosic biomass-to-ethanol technologies to tap the enormous energy potential of biomass for the transportation sector.

The technology for making ethanol from wood or other cellulosic biomass is still substantially more expensive than making ethanol from starch, so it has not yet become a commercial reality. NREL is working to improve the technology to make cellulosic ethanol more competitive. One key factor where possible major gains are anticipated is in the cost of cellulase enzymes for breaking down cellulose to sugars; NREL has major contracts with the largest enzyme producers.

The Project

An Arizona consortium would access the new technologies via license, or partner with the enzyme companies, to take advantage of these new developments and obtain financing for a plant that would be co-located with one of the proposed biomass plants.

Resource Needs and Sources

The NREL Web site, <http://www.afdc.doe.gov/pdfs/3957.pdf>, shows a "process design" for producing ethanol from wood chips, which outlines plant capital costs and cost reductions expected with new technology introduced during 2005 to 2010. A CRADA between an Arizona company or industry consortium and NREL might be possible to obtain DOE matching funds for a plant demonstration.

Time Frame

Timing will depend on the enzyme development schedule because private financing will depend on a more efficient, economic process. It is recommended, however, that talks begin soon with experts at NREL, and perhaps a license option be negotiated with the enzyme companies, to secure rights to the new technology.

Action 3: Develop a set of supportive policies and incentives that will grow the solar-based industry and measure progress

To promote new investments in solar-based projects and businesses, policies need to be re-examined and modified to encourage and provide incentives for risk taking by the private sector. Near-term actions might include the following:

- **Net Metering**—Establish true net metering to simplify customer relations and solar marketing. Currently, about a fourfold discrepancy exists between average buy cost from the utility and average sell price to the utility. This discrepancy is greater when summer peak rates are involved.
- **Environmental Portfolio Standards**—Increase renewable component, ramping up to 10 percent by 2010, with solar percentage at 50 percent.
- **Tax Incentives**—Implement meaningful tax incentives to attract and support solar-based businesses, including solar agri-biotech and forest-based industries.

- **Make solar a key element** in economic development, environmental quality, and energy reliability, specifically
    - Buildings: Make evaluation of renewables mandatory on all state buildings and public schools, with minimum 10 percent of square feet by given year.
    - State lands: Install solar and other appropriate renewable equipment and outreach at parks, rest stops, and principal airports.
    - Emergency facilities: Introduce solar backup systems at hospitals, firehouses, police stations, communication and transportation facilities, and other emergency facilities.

Resource Needs and Sources

The Governor's Solar Council should spearhead this action since it is critical to Arizona's future as a solar state. It ties nicely to the Strategy Five recommendations.

Time Frame

Immediate

Strategy Three: Make Arizona a sustainable manufacturing "Center of Excellence."

Manufacturing development in the new millennium will focus on developing processes that are more sustainable and that give both environmental and economic benefits. The overall objective is for firms to reduce their environmental footprint through their plants and their products.

The large, global semiconductor companies in Arizona, such as IBM, Intel, ST Microelectronics, and Motorola, have corporate-level programs that address workplace ES&H and product design for the environment. Many have greatly reduced their water, energy, and toxic materials use in their plants and are manufacturing products that are "greener."

The cost savings represented by new green technologies make a compelling business case. The market for sustainable manufacturing systems will increase with the growth of the industries committed to achieving "environmental neutrality." In many cases, new, more stringent regulations will be the primary driver (e.g., the EU plans to phase out use of all toxic materials by 2007). Existing manufacturing plants will be retrofitted, and new plants will be outfitted with energy-efficient heating and cooling systems, water recycle and reuse systems, and liquid and solid waste reduction systems. Use of toxic materials in the manufacturing processes will be phased out. The "holy grail" is ZDM, or zero discharge manufacturing; and, again, the European Union is moving companies in that direction by making them responsible for their products through their entire life cycle. Battelle recommends that Arizona accept this as a goal for its manufacturing industries.

Action 1: Evolve to a ZDM state—zero discharge manufacturing

The Project

This project involves a series of steps to highlight the leadership of the semiconductor industry cluster in sustainable manufacturing, encourage further advancements, and develop a technology transfer program for dissemination to all other industries in the state. Steps include the following:

- Encourage growth of the semiconductor cluster with its sustainable manufacturing focus, through a state recruitment campaign (i.e., make it feel valued).
- Encourage growth of sustainable product manufacturing by including such requirements in state purchase specifications. Leverage Arizona's distinctive competence in water management, from purification to wastewater cleanup and recycle, and make it a theme of state marketing materials.
- Leverage Arizona's solar energy potential by including solar heating/cooling equipment and solar electric power units on manufacturing campuses.
- Transfer the semiconductor sustainable manufacturing experience to biotech and biobased products industries and other manufacturing via special training programs. ZDM courses would be developed by joint industry-university groups and delivered via traditional professional education programs in colleges and universities.

Resource Needs and Sources

These needs can largely be satisfied by leveraging existing programs, in particular the state marketing and recruiting programs, state procurement program, and university education programs. However, success is contingent on the willingness of the semiconductor companies to share their approaches and experiences with other manufacturing industries in the state. The Center for Environmentally Benign Manufacturing at the UA, which deals with this industry, could coordinate efforts. The Center could add a task of outreach and technology transfer to all other Arizona manufacturing firms. Funding could be obtained from the DOC's Manufacturing Program.

Time Frame

Most of these steps could be taken in the first year.

Action 2: Develop and implement *signature* demonstrations

The objective is twofold: First, to further refine sustainable manufacturing in the existing semiconductor and embedded system industry clusters through improved use of water and solar energy; and, second, to grow a new industry segment around the manufacture of "green products." Two examples illustrate this approach.

Demonstration #1: Improve Industrial Water Recycle Using the Neopurification Process

The Project

The semiconductor industry could tap into a potential source of water by recycling some of the large volume used in the manufacturing operation. The UA's Center for Environmentally Benign Semiconductor Manufacturing is working to develop neopurification processes that will produce ultrapure water from manufacturing wastewater, along with reducing energy use and limiting chemical application.

Center researchers rely on a pilot plant to simulate operations within an actual industrial plant. The pilot plant is a physical model, larger than lab-scale, which enables researchers to conduct studies and apply and test their results under simulated industrial conditions. Contaminants in ultrapure water are measured in very low parts per billion and even parts per trillion, which may be two or three orders of magnitude purer than drinking water quality.

Signature Demonstrations for Sustainable Manufacturing

- Industrial water recycle using the neopurification process
- Manufacture of green building products

The Center has a $2.5 million pilot plant and laboratory, located on the UA campus. It is proposed that a project be developed to take the full water recycle to the next scale and demonstrate the system at a semiconductor fabrication plant or equivalent manufacturing facility.

Although the semiconductor industry drives much of the research devoted to ultrapure water, other fields also stand to benefit from the results. Certain pharmaceutical and medical specialties require ultrapure water. Also, biotechnology, an increasingly important activity in Arizona, will benefit from the techniques and technologies developed at the Center. Therefore, a second demonstration at a biotech plant also should be considered.

Resource Needs and Sources

This effort is likely to cost $5 million to $10 million per installation. The best funding model is company/industry match to federal grants via CRADAs.

Timescale

The semiconductor fabrication demonstration of complete water recycle could be implemented in 1 to 2 years, while the biotech application would be phased in over 2 to 3 years.

Demonstration #2: Manufacture of Green Building Products

The Projects

Two Arizona companies are pioneering new technologies for green building products, and each has demonstrations planned or in progress.

AerRock LLC has moved recently to Arizona and is designing—and soon will be constructing—a 60,000-square-foot manufacturing plant in Eagar, Arizona. The company

uses a proprietary technology that it has developed over the past 5 years to produce new, lightweight, exceptionally strong building panels of fly-ash cement. These panels can be made into a highly durable wall system that resists fire, insects, and rot. The company plans to add roofs and floors to its capability. Indeed, the first building to be constructed in Arizona from this new technology will be the 60,000-square-foot plant itself.

AerRock's manufacturing technology makes continuous, complex cross-sections into complete wall sections, consisting of outer and inner surfaces, as well as structure and insulation, at high speed. No drywall or siding is needed because the product is made almost entirely of waste materials. And, because it has a high thermal insulation, it is exceptionally environmentally friendly.

AerRock will be funded by a Midwest company that is funding housing developers across the country. Its intention is to introduce AerRock to these developers. AerRock has formed an alliance with a Phoenix-based developer, and a 2,000-home development is in the early planning phase. AerRock will produce a competitively priced, premium building product.

Strata International Group is a beta stage company that utilizes a new, innovative, sustainable building technology. Known as the Saebi Alternative Building System (SABS), this technology builds houses and low-rise buildings using composites of expanded polystyrene (styrofoam) coated on both sides with proprietary fiber-reinforced concrete for all structural members. External walls, roofs, floors, etc., constructed of these components provide a nearly airtight building envelope.

These commonly used, inexpensive building materials, characterized by their light weight, thermal-insulating, sound-attenuating, durable qualities, can be used in the building industry because SABS developed a patented method of predicting the structural performance of the entire building as it responds to any simulated structural loads. The method optimizes the design of each structural member to best fit both the structural and thermal-resistance requirements specified, thus minimizing waste of material.

Strata, together with Southwest Architectural Casting Corporation, masters in the craft of applying fiber-reinforced concrete, and Highland Products, Inc., foam manufacturers, are proving the practicability of using the radically different SABS by building a full-scale prototype of a 14-foot by 23-foot guest house in Phoenix. Additional alliances include 3M Corporation and German-based Hilti Corporation. These companies provide adhesives and bonding agents to create the form of Strata's composite structures.

Resource Needs

AerRock needs $25 million to build the plant and roll out volume product. Although the company is in discussions with one funder at present, all options are still being held open.

Strata International Group will need housing for its office, design and structural analysis teams, and a training team. It intends to provide its current technology and future improvements to the U.S. market and the global community by contractual relationships with architects, builders, foam companies, and other interested parties. Several new buildings, both single family and multifamily, are under consideration in Arizona and elsewhere.

Both companies probably will require changes in building codes, as codes typically are written around brick, block, and 2 x 4 wood systems.

Time Frame

Ongoing

Action 3: Create a Product Development Center to develop and "showcase" sustainable products

The Project

With the kind of market potential offered by "green products," Battelle recommends Product Development Centers for Sustainable Manufacturing that emphasize both the processes in the plant and the materials in the product. Potential locations include Phoenix/Tempe, Tucson, and Flagstaff, each perhaps featuring products of relevance to their areas. The "feedstock" for the Centers will be the new advances in materials, afforded by nanoscience and technology that make "green products" a reality. Arizona's universities are working in this new area of science and technology, and several entrepreneurs in the state are interested in taking such developments to market.

Resource Needs and Sources

Strategy Five describes the ideal characteristics of a Product Development Center. It is proposed that, as far as possible, the Product Development Center(s) be located in existing and planned facilities, which will significantly lower the cost of establishing them. However, it is anticipated that one-time funds for equipment and annual operating funds for staff and operations will be required. Battelle's recommendation is to target $3 million to $5 million per Center for equipment and $0.5 million to $1.5 million per year for operating costs. A mixture of fund sources will be needed, including federal and industry grants and contracts, fees for service, and, later, license royalty streams.

Timescale

One or more Centers could be implemented over a 2-year period, depending on funding availability and industry support.

Strategy Four: Establish a national and international image for Arizona as the "arid lands livability" state.

An important success factor for this initiative is a progressive increase in Arizona's image as a sustainable development leader nationally and internationally. A number of coordinated actions will be required to achieve this outcome.

Action 1: Appoint a state "Sustainability Czar," reporting to the Governor, and the Sustainability Council, composed of thought leaders

The following steps are recommended:

- Install a Sustainability Czar reporting to the Governor. Empower this official to gauge public interest, propose new policies and projects, and build coalitions among important stakeholder organizations.

- Impanel a Sustainability Council, appointed by and accountable to the Governor, which would be responsible for developing and managing the sustainability roadmap and setting metrics. It should be composed of sustainability experts drawn from government, tribal, industry, and academic organizations and NGOs. In future years, it could conduct a performance measurement process using a set of sustainability indicators appropriate to Arizona and issue a periodic "State of Arizona Sustainability" report.
- Create a process for the general public to become directly involved in developing and implementing a sustainability vision for the state. Arizona should consider providing a set of scenario-building tools via the World Wide Web, creating a process for capturing public ideas, preferences, and reactions to new sustainability initiatives and reflecting that knowledge in administrative actions, legislative initiatives, and public education campaigns. The Arizona effort could be modeled after similar initiatives in Canada and Europe.
- Establish a long-term benchmarking relationship with select states/regions (e.g., New Mexico, Australia) in which best practices are shared, visiting experts are hosted, and common needs are addressed through collaborative projects.
- Hold an annual meeting with key stakeholders to assess state performance against goals.

Resource Needs and Sources

To show the state's commitment to sustainable development, the critical first step is appointment, by the Governor, of the "Sustainability Czar." Given the state budget situation, the Governor should name someone in an existing position, either from the Governor's immediate staff or from one of the state departments (e.g., energy, environment). In any event, the position should be established as a senior staff function reporting directly to the Governor.

To assist the Czar in this monitoring process, it also will be important to appoint a Sustainability Council, composed of high-level stakeholders. These volunteer thought leaders, drawn from all sectors of Arizona society, will not only assess progress, provide solutions to problems, and propose enhancements, but, through their positions, will help communicate to the citizens of the state that Arizona cares about its future. At a minimum, suggested members of the Sustainability Council should include legislators and leaders of industry, NGOs, the tribes, and universities. The Council could be a subgroup of the GCIT, or it could be standalone.

Time Frame

In the first 6 months, the Sustainability Czar should take the responsibility for converting the Prospectus to a 10-year roadmap, with annual measurable goals, drawing in relevant government departments, NGOs, industry, and universities to provide the details. It will be his or her responsibility to champion, facilitate, and monitor progress of the roadmap. The Sustainability Council also should be put in place during the first 6 months.

Action 2: Create the Arizona Sustainable Systems Industry Association (ASSIA)

Battelle's proposal is to build on the ETIC base and refocus it to embrace all sustainable industries of relevance to Arizona. Following the change to the enhanced "charter," the new ASSIA should

- Undertake a new membership drive to capture suppliers, manufacturers, and users of sustainable products.
- Coordinate with the S^3T Collaboratory (see Strategy Six) on leveraging federal research, development, and demonstration (RD&D) grants and creating issue-oriented industry consortia.
- Apply for DOC EDA-type grants to help member companies with business growth (e.g., seed funds, incubators).
- Hold an annual Sustainability Conference in Phoenix to showcase Arizona's developments, coordinated with the Southwest Renewable Energy Fair in Flagstaff.
- Charge the UA's International Arid Lands Consortium with conducting a global market analysis for Arizona products/services.
- Team with the Arizona Department of Commerce and appropriate federal agencies on trade missions to other arid lands in the world.
- Develop and staff industry recruiting teams with the Arizona Department of Commerce.

Resource Needs and Sources

Just as for ETIC, it is expected that the expanded ASSIA will be driven and funded by its members. However, Battelle also recommends an enhanced search for support from federal agencies and foundations to carry out specific programs. ASSIA could serve as the industry focal point for joint university-industry programs that can access funds from several federal agencies, including DOC, USDA, DHS, DOE, etc. Also, ASSIA might well be a candidate for nontraditional funds (see Table 21).

Time Frame

The transition from ETIC to ASSIA could occur over 2 years. However, a proposal and plan should be developed in 2004, approved by the ETIC Board, and introduced at stakeholder meetings around the state, to gauge the level of interest in the broader charter.

Action 3: Undertake an educational and marketing campaign to increase Arizona residents' knowledge and understanding of sustainable practices

An educational and marketing campaign should be initiated that seeks to increase Arizona residents' knowledge and understanding of sustainable systems, the role they play in their lives, the opportunities they provide for them and their children, and the role they play in Arizona's economic future. Specific activities contained in the plan could include the following:

- Making public service announcements
- Sponsoring topical documentaries—water, forests, etc.
- Highlighting successes of sustainability initiatives in the press and speeches
- Working with the educational system on new courses and training opportunities
- Creating annual Governor awards for sustainable activities.

Resource Needs and Sources

NGOs such as Valley Forward would be very capable of organizing and coordinating such a campaign. Battelle recommends that it be approached to undertake this effort, singly or via a consortium with other NGOs and the public TV and radio service. Funding sources include the state and sustainability-focused foundations (see Table 21).

Time Frame

A plan should be developed in the first year, funding identified, and implementation begun in year 2. This continuing effort will take advantage of developments in all the other strategies for its source materials.

Action 4: Create a "Blue Ribbon" Panel to assess all current state and local standards, codes, and regulations pertaining to energy, water, environment, land use, and construction and to make recommendations on changes

It is recommended that the Governor appoint an expert panel that includes scientists, state and local regulators, industry leaders, and NGO representatives and charge it with a top-to-bottom assessment of all standards, codes, and regulations related to sustainability. In the process, the Panel also should consider the following:

- Evaluate converting command-and-control regulation to performance-based incentive systems where practical.
- Consider instituting Arizona as a "Natural Step" state, which would make it the first in the nation. With a Natural Step expert team, the state can create an innovative blueprint for sustainability that will
    - Give companies a competitive advantage by strengthening brand value, securing customer loyalty and trust and reducing risk.
    - Move industry and society at large toward long-term sustainability.
- Apply for ISO 14,001 environmental management certification (http://www.iso14000-iso14001–environmental-management.com/), which would make Arizona the first state in nation to do so.

Given the near-term needs associated with water management, it may be appropriate to have separate groups addressing water and energy and materials. A start has been made to address water issues, but the scope should be broadened to focus on a science-based set of water regulations that will propel Arizona to the lead in water management. In other words, Arizona should address the long term, not just the exigencies of the day.

With respect to energy and materials, Arizona could enhance the opportunities for new disruptive technologies to be introduced into the marketplace. Some bold moves have

been proposed with respect to the Environmental Portfolio Standards, building standards, and requirements for state material purchases. These need to be considered very carefully from a total life-cycle cost-benefit basis.

Resource Needs and Sources

This effort has to be state driven, from the top, since it is critical to overall success. Arizona must be perceived as a "sustainable" state in all that it does and have the supporting policies, regulations, and standards to encourage sustainable development at all levels. While many of the expert resource needs are readily available in universities, industry, NGOs, and governments, state funds (from reprogramming current budgets) will be required to support staff and specific special studies. An estimated $200,000 to $250,000 per year will be needed to support this Panel.

Time Frame

This should be the first action of the Sustainability Czar, following establishment of the Sustainability Council, in the first 6 months. A 1-year goal for assessment and recommendations for changes should be imposed on the Panel.

Action 5: Market Arizona as a prime location for companies manufacturing/servicing sustainable systems, and develop the *"arid lands livability"* label

Battelle proposes that a marketing strategy be developed to increase understanding of Arizona's assets for continued economic growth in an environmentally responsible manner. The strategy should emphasize the state's quality of life, scenic beauty, recreational opportunities, and health services, together with the strengths cited in this study. This is a very attractive set of attributes for companies and technically skilled workers, if packaged appropriately.

To that end, it is recommended that the state employ an advertising/marketing agency to create a state "brand" or "image" for arid lands livability. A well-publicized statewide competition for in-state firms only should be held to select the firm that will develop the omnibus brand for Arizona to unify state communication and marketing efforts. The goal is to identify the core values of the Arizona brand and implement key messages through a variety of marketing venues.

With a common set of state marketing materials in hand, the next step is to develop a marketing strategy and timeline with the Arizona Department of Commerce and industry associations, emphasizing the state's sustainability infrastructure and support network.

EXAMPLE: ENERGY EFFICIENCY CAMPAIGN

Coates Kokes has kicked off a new advertising campaign for ***BetterBricks***, a nonprofit initiative of the Northwest Energy Efficiency Alliance.

BetterBricks connects building professionals with information, tools, training, and consultation services at no cost or nominal cost.

The campaign consists of six ads that inform the construction marketplace about opportunities involving high-performance commercial buildings.

One of the ads is of particular relevance to Arizona:

"WHAT HAPPENS WHEN YOUR DESIGN IGNORES THE EFFECTS OF THE SUN? YOUR CLIENT GETS BURNED."

While initial markets will be mainly in Arizona and the Southwest, it is not too early to plan the global marketing of the "arid lands livability" products and services, key elements of which should be to create state trade offices in target countries like China and to hire experts on target countries to assist firms in their marketing efforts.

Resource Needs and Sources

A state marketing campaign is the responsibility of the state Department of Commerce, but industry could be persuaded to cost share aspects of the campaign that target their particular market segments.

MADE IN ARIZONA: THE ARID LANDS LIVABILITY STATE

This product was developed, manufactured, and qualified in Arizona for applications in arid/semiarid lands around the world. You can be assured that the rigorous testing in our hot, dry climate means that this product will perform well in your home or business.

MESA, Ariz. (May 8, 2001) — Amid temperatures over 100°F, General Motors set a series of records with the "HydroGen1" fuel cell concept car. "HydroGen1" set 15 international records during four weeks of endurance testing at the GM Desert Proving Ground near Mesa, on the outskirts of Phoenix.

Time Frame

The search for the marketing company that will develop the state brand should be started immediately. The first "marketing packet" will assemble the current considerable asset base, but these should be updated annually to reflect progress in building the sustainable infrastructure and qualifying new products and services. A 5-year plan that progresses from regional and national to international should be prepared.

Strategy Five: Create the business infrastructure for a sustainable systems industry to flourish.

A "user friendly" business infrastructure is an important ingredient for creating a new industry cluster. Companies today can locate anywhere in the world, so Arizona must develop a compelling case to retain and attract companies operating in this market space.

However, the Arizona "value proposition" should contain urban and rural livability elements, as well as the infrastructure that directly supports business growth, which is the focus of the actions below.

Arizona should address urban and rural livability issues—urban sprawl, commute times, pollution, water supplies and purity, energy supply, and quality of schools. All of these factors and more go into company decisions to expand in a particular area or to relocate. While some of these have been included in this Prospectus, others apply to growth in general and are beyond the scope of this project. Battelle is, nevertheless, encouraged by actions of several groups, including the state universities, which are trying to find solutions to these problems.

Action 1: Implement the recommendations of the Governor's Council on Innovation and Technology (GCIT) to institutionalize the "T+3M" model for new sustainable business creation

Unfortunately, there is no tried-and-true model for successful technology transfer. But, this often random process can be helped by creating an environment for innovation. The key to success is to integrate a series of "best practices" into a repeatable system.

Key services that should be made available are contained in the "T+3M" (i.e., Technology plus Money, Management, and Marketing) model for new sustainable business creation. Resources should be provided for each component, and the recommendations of the GCIT go a long way toward achieving this goal.[76]

- **Technology**—Enhance management of university IP to ensure invention capture and protection and the ability to bundle IP. Establishing an Arizona-wide system for bundling IP will be critical to the success of new product development in this market sector. Adequate funding for patent protection must be provided, including a system to evaluate its market potential. Methods should be introduced to give wide exposure to IP. For example, IP can be posted on Web sites that function as brokers, matching technology to needs of individuals or companies. Also, the universities should develop flexible licensing agreements that properly address the state of the technology and the market, and the industry partner's needs (i.e., one size does not fit all). An important new development is that the state has amended its constitution to allow public universities to take equity positions in new start-up companies that result from faculty and staff research.

[76] The Governor's Council on Innovation and Technology, http://www.gcit.az.gov.

- **Money**—Creating a pre-seed fund (a discretionary, proof-of-principle, pre-prototype development fund to ascertain whether there is value from the research for commercial applications) and accessing private-sector seed and venture capital funds via a "VC/Angel network" are essential to ensure a continuous funding stream through "the valley of death."

  In line with the recommendation from the GCIT, Battelle proposes that state tax incentives be offered to attract highly qualified and "socially responsible" venture fund managers to locate an office in the state and make significant and sustained investment in Arizona businesses.

  Finally, creating a Small Business Investment Company (SBIC) is recommended, leveraging the Rural Business Investment Program (RBIP). Battelle believes that Arizona Multibank, a community development corporation, might pursue this opportunity.

Investment-Oriented Sustainability Associations

- Social Venture Network (SVN)
- Business for Social Responsibility (BSR)
- Social Investment Forum (SIF)
- Environmental Capital Network

Individual Investment Organizations

- Sustainable Asset Management (SAM), Switzerland
- New Energies Invest AG, Switzerland
- Silicon Valley Bank, U.S.
- New Alternatives Fund, U.S.
- Jupiter Investment Trusts (Global Green Investment Trust), UK
- Calvert Venture Investors, U.S.
- Catalyst Financial Group, Inc., U.S.
- Sustainability Investment Partners, Switzerland

SUPPORT FOR RURAL BUSINESSES

One opportunity to support new venture capital in rural Arizona is through the Rural Business Investment Program (RBIP), which is a cooperative program of the USDA and the Small Business Administration (SBA). The initiative will allow newly formed venture capital investment companies to leverage private capital funds with government financial assistance and to obtain both government and private grant resources for technical assistance. RBIP was created by the 2002 Farm Bill, with funding through the Commodity Credit Corporation to support $280 million in guaranteed debentures and grants for technical assistance. Under the new agreement, USDA will enlist SBA's expertise in venture capital financing and reimburse SBA for carrying out the day-to-day management and operation of the program. Program officials expect to begin accepting RBIP applications in about 6 months. SBA has offered to give special consideration to rural applicants in its SBIC program until RBIP is fully operating.

- **Management**—In cooperation with university business schools, Battelle proposes that training and networking programs be established that will enhance the entrepreneurial capacity and management depth in Arizona. Mechanisms to engage the private sector on a regular basis also should be devised. Industry needs regular exposure to the science and technology opportunities, and venture capitalists need to be exposed to business investment opportunities. Monthly "poster" shows with wine and cheese, business plan competitions, and brown-bag seminars have all proven useful. The UC-San Diego CONNECT Program is a good model to adopt. Also, staff need to be able to take entrepreneurial leaves to start up companies, to hold stock or options, and to

navigate the state's conflict-of-interest laws in ways that are user friendly and do not jeopardize careers. Two approaches adopted by ASU should be followed closely. It has created the Arizona Technology Enterprise, a for-profit company that will manage all technology commercialization for the university, and the ASU Technopolis, which is a one-stop shop of resources for entrepreneurs interested in forming new companies.

- **Marketing**—Use the region's business school faculty and student teams to develop in-depth market analyses of technologies and inventions. Establish an SBIR "alert" program and provide help to prepare winning proposals. While some aspects of this are being offered by ASU and UA, Battelle recommends more coordination between the business schools, sharing of tools and resources, and a broadening of state coverage.

Resource Needs and Sources

Aside from the investment capital needs that have been addressed, most of the resource needs can be inserted into existing university programs, either in the business schools or in the technology transfer offices. Both ASU and UA have recognized the need to be more entrepreneurial and are enhancing their programs. Sharing of tools and resources with NAU and the community colleges will be very important to ensure coverage across the state.

Time Frame

Overall, the various T+3M components could be phased in over 1 to 3 years through augmentation of existing programs. Most of the enhancements have models from other institutions, and so an immediate start is possible.

Action 2: Create several strategically located product development centers, focused on the three segments—water, solar, and sustainable manufacturing

The three main market-creation strategies described above proposed Product Development Centers. These would be designed as "showcase" facilities to

- Produce a regular stream of innovative, perhaps disruptive, technologies or products that will position Arizona as a leader in sustainable systems
- Be applications oriented, utilizing several of the university core competencies in a "systems approach"
- Have robust and "evergreen" technology platforms, to address current as well as new, emerging market opportunities
- Require cross department and cross university collaborations—brand new "teams" as well as enhanced existing teams
- Partner with industry to provide "customer perspective" and "productization" skills.

The Centers would

- Include one-of-a-kind equipment or facilities that enhance the current or planned capabilities of Arizona's research institutions and industry
- Operate as "user facilities," shared by research institutions and private industry
- Focus on translational research, i.e.,, activities undertaken to increase the commercial value of Arizona's inventions
- Emphasize the development of products that will support the growth of emerging market sectors and the creation of brand new market sectors
- Leverage and influence federal investments in RD&D
- Be networked to institutions conducting basic science research and the companies that are the end users of the technology being developed
- Be inherent demonstrations of sustainable design and construction practices
- Provide demonstration and test-bed facilities as well as testing and evaluation services (e.g., manufacture limited quantities of prototypes for testing; access to a computer-aided design facility to provide software development and simulation).

Product Development Centers

Provide access to equipment and facilities to enable universities and industry to work collaboratively to adapt, develop, and utilize platform technologies:

- One-of-a-kind equipment
- Operate as user facility
- Focus on translational research to produce new products
- Provide training for students and entrepreneurs
- Leverage federal and industry funding

An additional attractive feature could be availability of space to incubate entrepreneurial start-up companies. Such an infrastructure would help Arizona pass its competitors in these areas by reducing time from laboratory to market.

Given the dispersed nature of Arizona's research institutions and technology industries, the Product Development Centers will need to be geographically dispersed virtual facilities, located in proximity to or within existing or planned research centers (e.g., the Hub-Node system as practiced in Michigan's Bioscience Corridor).

As the focal point for innovations emanating from R&D, the Product Development Centers will be part of the "Collaboratory" environment, combining the secure remote operation of special instruments with real-time videoconferencing, real-time computer display sharing, and other capabilities to make the Centers' capabilities accessible to remote users.

Resource Needs and Sources

It is proposed that the Product Development Centers be located in existing and planned facilities, which will significantly lower the cost of establishing them. However, Battelle anticipates that one-time funds for equipment and annual operating funds for staff and operations will be required. It is recommended that $3 million to $5 million per center be targeted for equipment and $0.5 million to $1.5 million per year per center for operating costs. A mixture of fund sources will be needed to develop the products, including federal and industry grants and contracts, fees for service, and later, license royalty streams.

Time Frame

The three main Product Development Centers—water products, solar products, and sustainable manufacturing products—could be phased in over a 3- to 5-year period, as funding allows.

Action 3: Develop eco-industrial parks around sustainable industries, e.g., green construction materials, high-value bioproducts, sustainable agriculture and forest-based industries, and sustainable manufacturing

As described for Strategy Two, three proposals exist that could be implemented in the form of eco-industrial parks. The six key elements of an EIP are

1. **Natural Systems**: The park must fit into its natural setting in a way that minimizes environmental impacts while cutting operating costs.
2. **Energy**: The park seeks greater efficiency in individual building, lighting, and equipment design and provides an on-site renewable power source.
3. **Material Flows**: Use of all materials is optimized, and use of toxic materials is minimized. The park is anchored around resource recovery companies that are start-ups or recruited to the location.
4. **Water Flows**: Processed water from one plant is re-used by another (water cascading), passing through a pretreatment plant as needed.
5. **Park Management and Support Services**: Management supports the exchange of by-products among companies and helps them adapt to changes in the mix of companies through its recruitment responsibility.
6. **Sustainable Design and Construction**: Buildings and infrastructure are designed to optimize the efficient use of resources and minimize pollution generation. The park is designed to be durable, maintainable, and readily reconfigured. At the end of its life, materials and systems can be easily reused or recycled.

Resource Needs and Sources

These are all private sector initiatives, with funding from banks and other private sources. Federal grants can be applied for to accomplish specific tasks, ranging from new infrastructure to technology commercialization. The most important role for the state is to assist with permitting and local land use decisions. Also, as discussed below, these eco-parks may qualify for several nontraditional funding sources.

Time Frame

The eco-industrial parks proposed as part of Strategy Two will be developed only if the anchor business is financed, so the timing is indeterminate. The two wood biomass power plants described earlier will anchor eco-industrial parks in Eagar and Yavapai County. Also, a third near-term opportunity might be the UA Science and Technology Park in Tucson, which could be modified to meet the eco-park criteria. The university is developing a 5- to 8-year strategic plan to expand the park and add 1.9 million square feet of office and research space, which could be a sustainable system demonstration.

Action 4: Attract funding from nontraditional funding sources such as private family funds, international development banks, etc.

In addition to traditional funding sources such as the government or established venture capital firms, several other organizations, such as family foundations and international development banks, are allocating money to sustainable development projects in North America and elsewhere. Energy- and water-saving projects, as well as others that focus on mitigating climate change and greening the state, are well positioned to obtain such funding. Battelle has treated this as a separate action because these funds could provide an alternative or supplementary strategy for exploring financial assistance aimed at sustainable development in Arizona. Examples of nontraditional funding sources potentially appropriate to the suite of strategies and actions presented in this Prospectus are described in Table 21.

Table 21: Nontraditional Funding Sources

Name	Description
1. The Wallace Global Fund	Established by Robert Wallace, son of the former Secretary of Agriculture and Vice-President under Franklin D. Roosevelt, invests its resources in projects that meet the following criteria: (1) Tackle root problems that impede progress toward a sustainable future; (2) Propose compelling strategies for promoting environmentally and/or socially sustainable development; (3) Offer potential for significant impact at the global level; and (4) Require private money, at least initially. Preference is given to activities likely to lead to broad policy changes, or those that leverage substantial new public or private resources. Fund encourages collaborations involving multiple NGOs and those with an interdisciplinary approach, particularly activities that utilize the combined resources of the public and private sectors.
2. The Energy Foundation	Based in California and launched by the John D. and Catherine T. MacArthur Foundation, the Pew Charitable Trusts, and the Rockefeller Foundation, it awards grants in the following areas: power (new energy resources and energy efficiency projects), building, transportation, national policy and analysis, climate program. The geographic focus is the United States, with special emphasis on regional initiatives.
3. Rockefeller Brothers Fund	The fund aims at promoting social change, peace, and sustainable development. The Sustainable Development Program of the fund aims at advancing cost-effective energy efficiency and renewable energy-based approaches to reducing greenhouse gas emissions, and promoting sustainable forest management practices.
4. The Pew Charitable Trusts	The mission of the Environment Program is to reduce the generation of greenhouse gases that contribute to global warming, conserve living marine resources with a particular emphasis on fisheries, and protect critical forest habitat and wilderness on public lands in North America. The program aims at promoting changes in the electric sector that increase the use of energy-efficient and renewable technologies as well as the generation of clean power.
5. North American Development Bank (NADB)	An international financial institution created under the auspices of the North American Free Trade Agreement and capitalized in equal parts by the United States and Mexico for the purpose of financing environmental infrastructure projects. All NADB-financed environmental projects must be certified by the BECC; be related to potable water supply, wastewater treatment, or municipal solid waste management; and be located within the border region. NADB is working to develop integrated, sustainable, and fiscally responsible projects with broad community support in a framework of close cooperation and coordination between Mexico and the United States. NADB oversees the Border Environment Infrastructure Fund to make environmental infrastructure projects affordable for communities by combining grant funds with loans or guaranties for projects that would otherwise be financially unfeasible. Only water and wastewater infrastructure projects located within 100 kilometers (62 miles) of the U.S.-Mexico border are considered for funding. A Water Conservation Fund and Solid Waste Environmental program are other projects under the NADB.

Demonstration: Engagement of Arizona's Native American tribal organizations in sustainable development/export projects.

One potential demonstration of the innovative use of nontraditional funding sources to promote sustainable development was suggested conceptually during a tribal organization's focus group conducted with Native American stakeholders in Arizona. A potential approach to implementing this concept is outlined here.

The Project

Native American tribes located in Arizona could demonstrate an innovative approach to funding projects that promote sustainability goals. Many tribal organizations are providing thought leadership in the sustainable development arena, but are seriously challenged in obtaining financial support for new economic or other development. The concept that emerged through focus group discussions is to attempt to develop the export potential of sustainable products created in Arizona, based largely on the credibility of Native American producers to consumers in developing country markets. This could be initiated through the leveraging of multiple sources of nontraditional funding. It would also create jobs for the Native American population while advancing the goal of sustainability in Arizona.

The project would entail establishing a core financial arrangement between one or more Arizona tribal organizations and one or more of the financing organizations of the type listed above, for the purpose of demonstrating the production of sustainable technologies for selected international export markets. The inducements to a source of venture capital might include tax advantages for businesses sited on tribal lands, as well as the marketing advantages that could be developed by directly linking Native American suppliers with buyers, particularly in developing countries, which may value the sustainability ethic inherent in the products offered. Some tribal organizations are beginning to creatively use their substantial storehouses of indigenous knowledge, localized governance structures, and deeply held respect for the environment to develop economic enterprises that define a sustainability business ethic.

Initiatives in the Pacific Northwest

Native American groups are working to cultivate (in production-scale nurseries) native plant species that were sources of traditional human value (food, medicine) and that in predevelopment times provided important habitat for fish and wildlife, which are now becoming endangered species. They are making them available on a commercial basis for watershed restoration projects sponsored by government agencies and NGOs.

The Makah Tribe in the State of Washington is collaborating with the AquaEnergy Group to develop a 1-MW pilot plant to demonstrate renewable energy generation from offshore wave energy. Aqua Energy Group, Ltd., the Makah Indian Nation, Clallam County Public Utility District, and the Northwest Energy Innovation Center have formed a consortium to bring clean and cost-effective renewable energy to commercial and residential consumers. At the same time, the project will bring social, economic, and environmental benefits to the Makah Indian Nation and the region.

Candidate sustainable systems for this demonstration project are drawn from the three core strategies and might include the following:

- Energy technologies such as wind turbines or solar systems that are scaled to small, isolated "off-grid' communities
- Water recycling technologies appropriate to isolated residential or light industrial locations
- Production of specialty bioproducts tailored to specific export markets made possible by sustainably designed greenhouse technologies.

In each case, the products might be exported as a "Native American Certified Brand," conceived and produced as sustainable in both manufacture and use. Alternatively, this concept could be focused on the export of tribal experience and information as a consulting service to others interested in developing sustainable energy, water, manufacturing, or other systems. This may be a more likely initial opportunity, requiring less start-up capital, but also producing fewer long-term economic benefits.

Resource Needs and Sources

Financing for a Native American sustainable export product concept could combine both traditional and nontraditional sources. Foundation or international development bank financing could be leveraged with U.S. government or NGO financing that is generally focused on tribal enterprises.

One potential source of funding for tribal enterprises is typically the U.S. federal government. Several federal agencies have programs focused on economic and sustainable development of tribal lands, the most active of which are EPA, DOE, DoD, and DOC (SBA), as described in Table 22.

Table 22: Federal Government Programs

Agency	Program Descriptions
DOE	1. EERE administers the Tribal Energy Program. It promotes tribal energy self-sufficiency and fosters employment and economic development on America's tribal lands. The program offers financial and technical assistance for renewable energy feasibility studies and shares the cost of renewable energy projects on tribal lands. It also offers assistance to tribes for the initial steps toward developing renewable energy and energy efficiency projects, including strategic planning and energy options analysis. 2. The 2003 Hydrogen Fuel Cell Act authorizes $20 million over six years (2005–2010) for DOE, in cooperation with Native American tribes, to develop a strategy for demonstration and commercial application of hybrid distributed power systems on tribal lands that combine renewable and fuel cell power generation technologies.
DoD	DoD has been actively involved in working with tribal governments to finance and demonstrate promising, innovative technologies that target environmental problems caused by DOD's past activities on Indian lands. These projects are aimed at implementing innovative cleanup technologies as well as transferring information to Indian communities. DoD's Office of Small and Disadvantaged Business Utilization provides technical and business development assistance to Native Americans. DoD also sponsors environmental training and education opportunities and offers prime contractors an incentive for using Native-American-owned subcontractors or organizations (under DoD's Appropriation Act of 2000).
EPA	The American Indian Environmental Office coordinates EPA's agency-wide effort to strengthen public health and environmental protection on tribal lands, with a special emphasis on building tribal capacity to administer their own environmental programs. The EPA administers several programs, including Watershed Protection, Wetlands Protection, Solid Waste and Emergency Response, Tribal Air Program, and Drinking Water Program.

Table 22: Federal Government Programs (continued)

Agency	Program Descriptions
DOC (SBA)	The Office of Native American Affairs is dedicated to ensuring that American Indians, Native Alaskans, and Native Hawaiians seeking to create, develop, and expand small businesses have full access to the necessary business development and expansion tools available through the agency's entrepreneurial development, lending, and procurement programs.

In addition to U.S. government programs, Battelle recommends exploring several nontraditional sources for increased leveraging potential. Table 23 includes organizations that are aimed at promoting sustainable development through tribal organizations and could potentially fund tribal projects.

Table 23: Additional Nontraditional Funding Sources for Native Americans

Name	Description
1. Native Energy	Vermont-based company is aimed at helping develop domestic renewable energy resources with emphasis on Native American projects that create social, economic, and environmental benefits for tribal lands. In April 2002, Native Energy partnered with the Rosebud Sioux Tribe of South Dakota to create a wind energy project—the first of its kind built on the tribal lands. This wind turbine will help to offset a significant amount of CO_2 emissions from coal-fired electric generation by the local utility cooperative. Tribal officials see this first turbine as the start of an economic development initiative that will bring a vital industry to the reservation.
2. Indigenous Environmental Network (IEN)	Founded in 1990 at a grass-roots level by indigenous peoples, IEN aims at addressing economic and environmental justice issues. It is an information and networking forum for tribes, local communities, environmental organizations, etc.
3. Honor the Earth	National foundation and advocacy organization supports Native American environmental work. Its mission is to increase funding and public support for Native American communities protecting the environment. Honor the Earth established the Renewable Energy and Conservation initiative, which promotes solar energy and the construction of small-scale wind turbines.
4. Inter-Tribal Environmental Council (ITEC)	The mission of the ITEC is to protect environmental and natural resources of the Native American population as well as provide technical support, financing, training, and services in a variety of environmental projects.

Time Frame

Battelle recommends a 2-year phase-in of tribal demonstrations, with the first year emphasizing learning about the various funding sources and the approaches to winning grants. The tribes need to work together during this phase to share information and experiences. Visits to the Northwest tribes and others that have had success with nontraditional funding will be an important part of the first-year preparations. In the second year, several proposals need to be developed and submitted for funding.

Strategy Six: Sustain and grow university and industry R&D.

While the research base at the three universities is strong, and industry-supported technology development is impressive, Arizona must not become complacent. There are gaps in research, particularly in renewable energy and bioproducts; and universities in other states are aggressively pursuing major initiatives with national laboratories, industry, and federal agencies. For Arizona to sustain and grow its core competencies in

sustainable systems, the three universities and partner companies must work as a collaborative system, rather than as separate units. Almost all new federal initiatives are going to university-industry consortia, and Arizona must internalize this model.

Action 1: Create a statewide Sustainable Systems Science and Technology (S^3T) Collaboratory that networks scientists and engineers across the state

To develop and sustain the core competencies, Battelle recommends that the various research organizations create "Technical Networks" and an associated "Collaboratory" Environment, via a series of actions, as follows:

Technical Network Best Practices*

Technical networks should

- Be competency based
- Align technical capabilities with the business strategies of their organization
- Link people across organizations and geographical boundaries
- Provide value to its membership
- Be responsible for achieving a common set of goals and held accountable.

**Source: Battelle, based on networking experiences of companies such as DuPont, Battelle, 3M, Hughes Electronics, Siemens, and Lockheed Martin.*

(a) Formalize Technical Networks around the core research areas. Networks are becoming a vital force within and across organizations as a way of linking technology and technologists, promoting information flow, and increasing efficiency. The foundations for strong technical networks exist in Arizona in the form of informal scientific networks among the research universities. However, these informal networks need to become core competence-centric and expanded to include research institutes and industry participants, and enhanced beyond simple information exchange. It is proposed that formal technical networks, around competencies such as water, solar energy, and manufacturing, be organized immediately and supported to foster the multidisciplinary collaboration needed between research and industry to achieve the state's technical and economic goals. The value to participants includes the expansion of their knowledge base, access to resources not available in their home institutions, and increased opportunities for collaborative R&D funding.

Each technical network would include specialists from the universities, research institutions, and industry in Arizona. Each participating organization could identify a Technical Network Leader for each network in which it wants to participate. The Technical Network Leader could serve as the in-house champion and point of contact for network members. All key scientific, business, policy, and engineering staff should be encouraged to participate in technical networks in their areas of competency.

Technical network activities could include developing and maintaining an inventory of network capabilities, conducting topical workshops or seminars sponsored by the partners, and developing joint research opportunities and contributions to new intellectual property and capabilities. Examples include forming interdisciplinary teams with industry to

1. Conceptualize new research or application centers that can leverage federal funds in growth areas such as hydrogen.
2. Develop R&D "Grand Challenges" that could be matured into a new federal laboratory (e.g., water and arid land ecology).

3. Identify industry test beds for technology demonstrations—the Product Development Centers.

The Collaboratory environment discussed below would be very useful in enabling the networks.

A Collaboratory

Provides access to instruments, data, and computer display sharing to enable researchers in different geographical locations to interact as if they were located much more closely.

Collaboratory toolkit allows for remote experiments, testing, and real-time data analysis.

Software includes

- Real-time Group Collaboration
- Virtual Network Computing
- Document sharing
- Remote access to instruments.

(b) Create a "Collaboratory" Environment. By their very nature, these core competency "platforms" are where collaborations are essential, not only among the university researchers, but with industry practitioners. Accordingly, Battelle believes that there would be great value in creating a Collaboratory for each area, in which the state's researchers can work cooperatively to further research and develop applications for technology without regard to geographical location. Hardware and software are available that can enable researchers to interact with their colleagues, access unique or otherwise prohibitively expensive infrastructure, share data and computational resources, and access information in digital libraries. By providing access to instruments, data, and computer display sharing, the Collaboratory would enable researchers in different geographical locations in the region to interact as closely as if they were just down the hall.The Collaboratory would integrate new communications technologies, including shared computer displays, electronic notebooks, and virtual reality collaboration spaces with videoconferencing and E-mail capabilities. These communication technologies also could be integrated with scientific and engineering resources, including instruments, data, analysis software, and the scientific literature. They would allow for remote experiments, testing, and real-time data analysis.

The Collaboratory toolkit that could be used in Arizona might include the following:

- **Meeting support**—Placeware or WebEx to hold group meetings.
- **On-demand screen sharing for in-depth work**—NetMeeting if Windows only, otherwise VNC and a VPN or secure shell.
- **Virtual Network Computing or VNC**—A secure collaborative (remote) instrument control application tool. VNC provides the authorization control and privacy essential for the safe control of expensive instruments or the sharing of sensitive data.
- **Document sharing**—Apache WebDAV and WebDrive (software that makes an Internet site look like a disk or network drive) or Docushare, depending on level of technical expertise available (Docushare will be easier to manage/use).

Collaboratory sites should be established in Phoenix, Tucson, and Flagstaff at a minimum. Depending on budgets, consideration also might be given to creating collaboration sites in some rural areas of the state, perhaps through community colleges or the extension services presently operated by the university system.

Resource Needs and Sources

The major resources for this Collaboratory are the software packages to enable real-time networking. Table 24 is a detailed list of available software. All costs are approximate and negotiable with vendors.

Table 24: Collaborative Technologies with Identified Strengths and Weaknesses and Contact Information

	Strength	Weakness	Information
Real-Time Collaboration Suites			
WebEx	• Hosted off-site, no administration costs • Participants need only a Web browser to participate in meeting • Allows screen sharing • Popular tool, used by many corporations	• Each participant is charged in 15-minute increments. Can be an expensive choice for meetings with many off-site participants at different locations • Video collaboration is additional charge • Telephone is required for audio portion of discussion	http://www.webx.com Cost—$5 per participant per 15 minutes, $6 for videoconferencing
Placeware/ Microsoft Office Live Meeting	• Similar to WebEx • Growing integration with Microsoft Office applications	• Cost • Requires telephone • No video	http://www.placeware.com $0.35 per minute per person, or about $75 month per concurrent user unlimited.
Lotus Instant Messaging and Web Conferencing (formerly SameTime)	• Can be hosted off-site or a server license may be purchased • Screen sharing, Instant Messaging, application sharing • Configurable installation • Strong commercial backing – IBM owned	• Software administration required if server is purchased	http://www.lotus.com/products/lotussametime.nsf/wdocs/homepage Cost—$122 per user Part of the IBM WebSphere Package
NetMeeting	• Comes standard with Windows OS • Audio/video/chat/shared applications • Easy to use • Can be brought into environment and added to Exchange Server 2003	• Without a reflector or configured to run against corporate Exchange server. Limit of two participants • Must be running a Windows computer to use • Uses multiple ports. Difficult to administrate from a network administrator standpoint	http://www.microsoft.com/windows/netmeeting/default.asp Cost—Free, can be tied to Exchange server; see Microsoft for pricing of Exchange server

Table 24: Collaborative Technologies with Identified Strengths and Weaknesses and Contact Information (continued)

	Strength	Weakness	Information
Real-Time Collaboration Suites (continued)			
Groove	• Peer-to-peer • Free demo downloads available • Very well respected developers • Extensible suite of tools including chat, shared documents, E-mail, etc.	• Peer-to-peer	http://www.groove.net/ Cost—Free to use, Professional Edition $149 each user
Access Grid	• Allows multiple institutions to interact in real-time room-based discussions • Very good environment for meeting with numerous people at multiple locations—multiple screens showing video, presentations, shared screens • Can be a good tool for presenting material	• Expensive to build • Expensive to operate • Research system • Standardizes on multi-cast for audio/video communications, which is not as widely supported on networks as is TCP/IP • Formal interaction model requiring a meeting administrator to control equipment	http://www.accessgrid.org Cost—Hardware = $50K Software—Free Administrator time required during meeting
Real-Time Collaboration Separates			
VNC	• Real-time application sharing • Available for most operating systems • Open Source—Many flavors of VNC are available • Java-based browser format available • Fast and easy to use	• Does not encrypt communications, relatively weak password protection—can be ameliorated by running VNC within an SSH session or with a VPN • Not as fast as some COTS products	http://www.uk.research.att.com/vnc/index.html http://www.realvnc.org/ Cost—Free/Open Source
VIC	• Videoconferencing • Available for most operating systems • Highly configurable • Open Source	• If sites are not multicast enabled, user must unicast (which makes this much like NetMeeting), allowing only two video participants. (Multi-session bridge can be used to fix this problem) • Highly configurable and therefore not user friendly	http://www-nrg.ee.lbl.gov/vic/ Cost—Free/Open Source

Table 24: Collaborative Technologies with Identified Strengths and Weaknesses and Contact Information (continued)

	Strength	Weakness	Information
Real-Time Collaboration Separates (continued)			
Canon VB-C10 Camera Server	• Easy setup • Runs via a Java applet in a browser • Operating system independent • End user can control the camera Pan/Tilt/Zoom features	• User can operate camera. This can be a problem with multiple users attempting to control the camera (work around is to delegate a control person)	http://www.x-zone.canon.co.jp/WebView-E/product/vbc10/ Cost—$1300 each
RAT (Robust Audio Tool)	• Open Source can be run on most operating systems • Can be multicast	• Difficult to operate • Voice over IP does not work as well as telephone	http://www-mice.cs.ucl.ac.uk/multimedia/software/rat/ Cost—Free/Open Source
Docushare	• Supports workflow management of documents • Works across networks and firewalls • Supports configuration management of documents	• Can be difficult to find documents using the Docushare Web interface	http://docushare.xerox.com/ds30/ds30.html
Apache WebDAV Server	• Document/data sharing • WebDAV is an extension of HTTP • Can be used with shareware/low-cost tools to make the shared repository appear as a networked disk drive		http://www.apache.org/ Cost—Free/Open Source
Web Portal Technologies			
CollabNet	• Inclusive system provides access to document sharing, configuration management, chat sessions, conferencing, messaging • Supports variety of operating systems • Built on Open Source technologies • Requires only a browser to interact	• Expensive product for a large work group • Administrative setup and configuration required	http://www.collab.net/ Pricing dependent on client and number of sites

Table 24: Collaborative Technologies with Identified Strengths and Weaknesses and Contact Information (continued)

	Strength	Weakness	Information
Web Portal Technologies (continued)			
SourceForge	• Based on Open Source technology • Widely adopted by the software development industry • Inclusive system provides access to document sharing, configuration management, chat sessions, conferencing, messaging	• Administrative setup and configuration required	http://sourceforge.net/ Cost—Free/Open Source Pricing negotiable for corporate usage
IBM WebSphere	• General portal/Web application system		http://www-3.ibm.com/software/info1/websphere/index.jsp?tab=highlights High initial costs and administration
Microsoft SharePoint			http://www.microsoft.com/sharepoint/ (Cost—Included with Exchange 2003, see http://www.microsoft.com/exchange/howtobuy/enterprise.asp)
CMCS Portal	• Very flexible portal system based on the Open Source Jetspeed and CHEF portal frameworks • Includes a WebDAV-based document/data repository that supports dynamic translation between data formats • Capable of tracking pedigree/provenance relationships between data files • PNNL is a lead developer • Chemistry and life science tools • Integrated electronic notebook	• Ongoing research effort just releasing an initial product • Significant configuration required	http://cmcs.org/ http://www.scidac.org/SAM/ Cost—Free/Open Source

Time Frame

Battelle recommends that the water and solar networks be put in place first, in year 1, as part of the Water Consortium and Solar Center initiatives. At least 6 months' experience should be gained with these before expanding into other topical areas. Sustainable manufacturing would be the obvious next network; but, for its success, industry would have to step up to the investment.

Strategy Seven: Develop the workforce talent pool to support the sustainable systems industries.

The goal of this strategy is to enhance the competitiveness of and increase the ability to "grow Arizona's own" skilled workforce to work in current and future sustainable industries. Its characteristics are very similar to those proposed as part of the Arizona Bioscience Roadmap.[77]

Action 1: Develop a statewide workforce education strategy for sustainable industries across the state

A statewide workforce education strategy for critical technology- and knowledge-based occupations that are central to the competitiveness of sustainable industries is needed. This was recognized in earlier studies that Battelle conducted for the Flinn Foundation and Maricopa County, and recommendations for specific actions have been made. Battelle recommends that the Sustainable Systems Platform "piggyback" these activities and ensure that their special technical or business needs are factored into any follow-on programs.

Action 2: Increase Arizona's higher education capacity to "grow its own" skilled workers in sustainable systems

The key objectives are as follows:

- Increase the number of people graduating with degrees in energy, environment, materials, and water engineering.
- Increase the capacity and quality of business and information management programs.

Ways to increase access to relevant college degrees, including coordinated curriculum, distance learning, and transferability of credits among the state's higher education institutions should be considered.

Action 3: Increase the number of students aware of and prepared to enter science and technology fields (particularly those aimed at sustainable development)

Efforts should include working with university and industry to develop high school courses in energy, water, and arid lands topics; developing an intern program for grades 10–12 so that young adults can experience businesses in operation; making the concept of sustainability a part of every course; and developing sustainable consciousness by

[77] *Platform for Progress: Arizona's Bioscience Roadmap*, prepared by Battelle for the Flinn Foundation, December 2002.

organizing "sustainability awareness campaigns" similar to antismoking or HIV-awareness campaigns.

Action 4: Increase the number of teachers who are competent in the use and application of technology in the classroom

A program should be developed to encourage industry- and university-sponsored involvement in curriculum development and teacher training; a scholarship fund should be created from foundations and industry contributions, which will provide teachers with time and resources to upgrade their technology skills; and teachers should be provided with industry internships and sabbatical leaves.

One area of focus should be with the two tribal colleges on Navajo and Tohono O' Odham lands. A new project called Project Native, started in 2002, and funded by the Office of Indian Education, trains Native Americans to be teachers. This would be an excellent program to inject curricula that emphasize sustainable systems.

Resource Needs and Sources

Recommendations for all four actions call for a much stronger partnership between school boards, universities, and local industry, which will bring with it co-investment in specific projects spanning the early grades and undergraduate years. Teams of school teachers, university professors, and industry leaders should be formed to develop new curricula for grades K–12. Special summer training sessions should be supported to "train the trainer."

In addition, Battelle recommends that the state establish a coordinating function that would seek out federal and foundation grant opportunities to enhance interdisciplinary science education at all levels.

Time Frame

As every study has concluded, this area is absolutely essential for technology-based economic development to prosper in Arizona, so actions must be started immediately. For sustainable systems, there should be a 5-year goal to have curricula and trained teachers in most grade schools in the state.

SUMMARY

Battelle has proposed 24 actions in seven strategies that, collectively, will help establish Arizona as a leader in sustainable development and ensure that the Arizona sustainable systems industry will grow and create high-value jobs through a stream of innovative products and services for arid/semiarid lands throughout the world.

In the previous section, Battelle identified five key "gaps" or areas that Arizona needs to close to achieve the outcomes desired. Table 25 shows that the strategies and actions align well with the gaps, as planned; and, if successfully accomplished during the next 5 years, they will position Arizona for the next big technology wave—sustainability.

Table 25: Role of Strategies and Actions in Closing Arizona Gaps in Sustainable Systems

Arizona Gap	Strategy One	Strategy Two	Strategy Three	Strategy Four	Strategy Five	Strategy Six	Strategy Seven
Research and Technology	Actions 1 and 2	Action 1				Action 1	
Product Manufacturing	Action 3	Action 2	Actions 1– 3		Actions 2 and 3		
Workforce Development							Actions 1–4
Business Climate and Infrastructure	Action 4	Action 3		Actions 1–4	Actions 1 and 4		
Market Creation	Actions 2 and 3	Action 2	Actions 2 and 3	Action 5			

Implementation

INTRODUCTION

This section of the Prospectus discusses development scenarios, critical actions to be taken in year 1, a 10-year financial plan, and measures of success and periodic performance evaluations

DEVELOPMENT SCENARIOS

The concept of sustainable development is rapidly evolving, embracing new ideas and innovations in an accelerating manner, and can therefore be daunting and confusing to many observers and participants. This Prospectus, proposing seven key strategies and a larger number of implementing actions, necessarily reflects that complexity. It should be recognized at the same time that actual outcomes cannot be specified with any degree of certainty at this time. Instead, it may be helpful to consider an overall scenario of how the strategies might unfold. The concept portrayed conceptually in this section is a comprehensive development scenario.

Figures 6 and 7 attempt to portray a development scenario in three dimensions:

- An initial 10-year time horizon
- A measure of strategic breadth, meaning that each strategy will be composed of several different elements and will not be unidimensional
- A measure of achievement of sustainability goals, meaning that each strategy will evolve and make a positive contribution to sustainable development in Arizona over time.

Using this three-dimensional framework, it may be helpful to first consider four of the proposed strategies as “enablers” or “building blocks,” as portrayed in Figure 6:

- Establish a national and international image for Arizona as the “arid lands livability” state
- Create the business infrastructure for a sustainable systems industry
- Sustain and grow university and industry R&D
- Develop the workforce talent pool to support the sustainable systems industry.

Collectively, these four strategies will provide the foundation and framework for Arizona to achieve leadership in one or more major areas of sustainable development. Parts of this foundation already exist, and it can be expected that implementation of these enabling strategies could be a continually expanding process, as new ideas in policy and regulation, education, and other mechanisms evolve and respond to the changes created by success in achieving sustainability. But, in and of themselves, these enabling strategies are insufficient to propel Arizona to national and international leadership. That is where the two primary “industry niche” strategies depicted in Figure 7 come into play:

Figure 6: Sustainable Systems Implementation Scenario—Build the Foundation

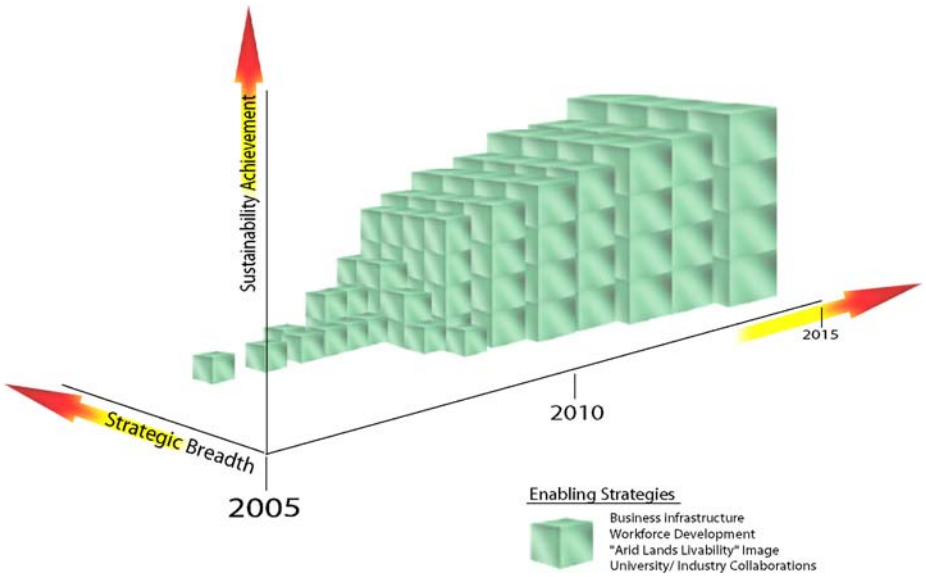
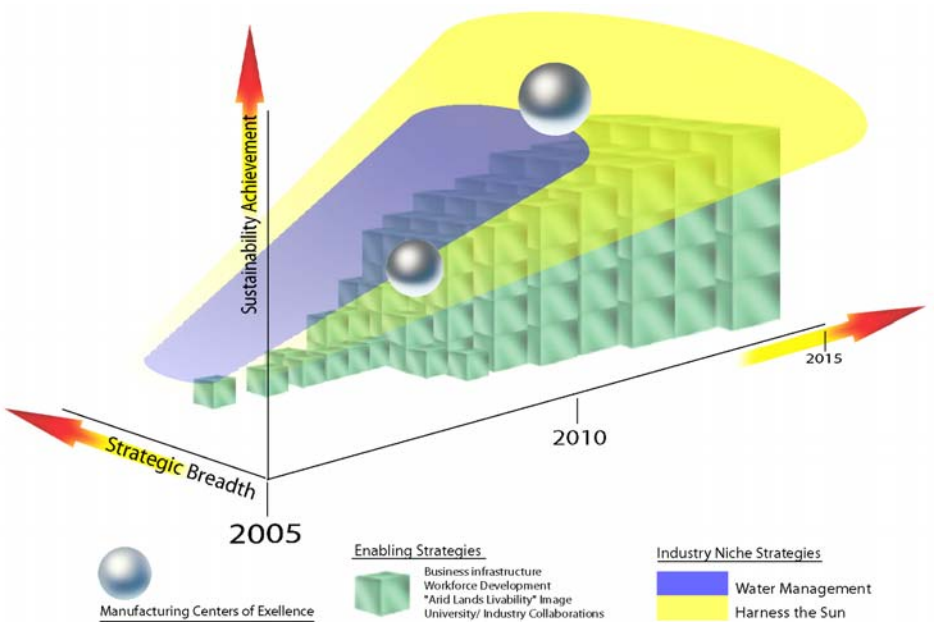


Figure 7: Sustainable Systems Implementation Scenario—Develop Niche Strategies



- Make Arizona the "Water Management Capital" of the world
- Harness the sun for power, fuel, food, and medicine.

These could be distinct visions for Arizona to pursue, and separate scenarios reflecting these niches could be constructed. Achieving success in either of these niches would be a major achievement that would produce many of the economic, social, and environmental benefits described in this Prospectus. Each of these industry niches presents a somewhat different potential development scenario:

- Sustainable water management probably has a finite limit of development over a 5-to10-year time horizon. One could reasonably expect to come very close to meeting a goal of "zero waste" for water resource use through technology improvements and adoption, and this would produce huge benefits and opportunities for Arizona. But, the benefits of sustainable water resource management beyond that point may level off.
- Harnessing the sun for power, food, fuel, and medicine, on the other hand, has the potential for an ever-increasing set of sustainability benefits arising from continual technological improvement and innovation. It is difficult to imagine a leveling off in this niche, especially as it is so basic to so many other sustainability needs and opportunities.

Finally, the strategy to "make Arizona a sustainable manufacturing Center of Excellence" might actually be achieved through the collateral establishment of centers of excellence in both water and solar energy niches, making this strategy a component of, rather than an option to, the water and solar industry niche strategies, as depicted by the spheres within Figure 7.

Again, a conceivable development scenario for Arizona is to pursue a subset of the niche strategies and those elements of the four enabling strategies required for the selected niche. But, a truly phenomenal outcome in sustainable development would be achieved if Arizona pursues all of these niches in parallel and specifically seeks to foster the synergies inherent among these niches through an integrated approach, as portrayed conceptually in Figure 7. For example, a center of excellence focused on high-value bioproducts, grown in solar-powered greenhouses that operate on 100 percent recycled water, would be a clear demonstration of such synergies.

SIGNIFICANT AND CRITICAL ACTIONS FOR LONG-TERM SUCCESS

Among the 24 actions identified in this Prospectus, eight stand out as most critical to the long-term achievement of the vision to establish Arizona as a major center of sustainable development across several research, economic development, and quality-of-life dimensions. These eight actions, which should be started first, are grouped into three equal areas of emphasis: (1) organization and management; (2) technology demonstration and commercialization; and (3) research and development.

Organization/Management

- Sustainability Czar and Sustainability Council
- Water, energy, and sustainable product policies
- Image/branding

Technology Demonstration and Commercialization

- High-visibility "signature" demonstrations
- New business investment funds
- Eco-industrial parks and product development centers

Research and Development

- Arizona Water Sustainability Consortium
- Arizona Solar Center

These critical actions are to some extent interrelated, particularly as they impact Arizona's ability to capture market share and its image/brand. Specific steps that should be taken in the first year are as follows.

Organization/Management

To show the state's commitment to sustainable development, the critical first step is appointment, by the Governor, of the "Sustainability Czar" (i.e., Sustainability Policy Adviser). Given the state budget situation, the Governor should name someone in an existing position, either from the Governor's immediate staff or from one of the state departments (e.g., energy, environment). In any event, the position should be established as a senior staff function reporting directly to the Governor and filled by an acknowledged expert in this emerging area. In a parallel action, legislative action to institutionalize the Sustainability Czar position would be very useful to ensure continuity across administrations.

In the first 6 months, the Sustainability Czar should take the responsibility for converting the Prospectus to a 10-year roadmap, with annual measurable goals, drawing in relevant government departments, NGOs, industry, and universities to provide the details. It will be his/her responsibility to champion, facilitate, and monitor progress of the roadmap.

To assist the Czar in this monitoring process, it will be important to appoint a Sustainability Council, composed of high-level stakeholders. These volunteer thought leaders, drawn from all sectors of Arizona society, will not only assess progress, provide solutions to problems, and propose enhancements, but, through their positions, will help communicate to the citizens of the state that Arizona cares about its future. At a minimum, suggested members of the Sustainability Council should include legislators and leaders of industry, NGOs, the tribes, and universities. The Council could be a subgroup of the GCIT, or it could be standalone.

A second major effort will be to assess all policies, regulations, and standards associated with sustainable systems. Given the near-term needs associated with water management, it may be appropriate to have separate "Blue Ribbon" Panels addressing water and energy and materials. A start has been made to address water issues, but it is suggested that the scope be broadened to focus on a science-based set of water regulations that will propel Arizona to the lead in water management. In other words, Arizona should address the long term, not just the exigencies of the day.

With respect to energy and materials, Arizona could enhance the opportunities for new disruptive technologies to be introduced into the marketplace. Some bold moves have been proposed in the strategies with respect to the Environmental Portfolio Standards, building standards, and requirements for state material purchases. These ideas should be considered seriously and be analyzed from a life-cycle cost-benefit basis.

These activities and those described below are tailor made for regular press releases from the Governor's Office that will start the image-building process. However, it is proposed that a statewide competition be held during the first 3 to 6 months to select the company that will develop the Arizona sustainability image and brand.

Technology Demonstration and Commercialization

Key to the success of this Prospectus is the qualification of new technologies/products that will create a manufacturing base in the state and the associated service sector, all producing high-wage jobs. Accordingly, it is important to start early with a few winners, and make sure that everyone hears about it. Recommendations for the first year include the following:

- Start at least two water projects—candidates are the AzMex High Quality Drinking Water Project, Phase 0; a small-scale demonstration of DEWVAPORATION in Phoenix; and the wastewater treatment plant in Nogales.
- Obtain a decision by an Independent Power Producer, Solel Solar Systems or SolarGenix, to site and build a large (>1 MW) solar plant in the state.
- Obtain the go-ahead for the biomass plant and associated eco-industrial park in Yavapai County. Endorsement by the state will help the county decide on competing uses for the land.
- Scale up the UA neopurification water technology into a center of excellence for sustainable manufacturing.

These signature demonstrations will be largely privately funded, but state and local support will be required in permitting and/or providing long-term contracts for the products. Some federal funds also can be won for R&D and commercialization activities.

A second key area that must be attacked during the first year is availability of investment funds for new business start-ups. In-state funding is lacking for sustainable systems innovations, from seed to later stage investments. It is, therefore, recommended that the state approach some of the socially responsible investment organizations noted earlier and offer an incentive package for them to locate an office and invest in Arizona start-ups. This recommendation is consistent with that of the GCIT. Income/property tax relief and first right of refusal on the IP generated in state might be sufficient to attract one or two of these companies.

Also, the Arizona Multibank should be encouraged to pursue creation of an investment fund through the Rural Business Investment Program. Applications will be requested in about 6 months. Such a fund would be of great use to small businesses and start-ups that want to locate in rural areas.

Finally, in the first year, some progress needs to be made on establishing eco-industrial parks and product development centers. The biomass power plants in Eagar and Yavapai also are proposed with industrial parks that will be eco-oriented, utilizing a wood products platform and also, possibly, greenhouse-grown crops. Another opportunity for gaining an eco-industrial park label is the UA Science Park in Tucson. Development of three eco-parks during the first 5 years of the roadmap would have a great impact.

Research and Development

Sustaining and growing the R&D base in universities and industry is critical to the sustainable systems future since it is the engine for growth of businesses and jobs. Given the desired image for Arizona, Battelle recommends two areas of focus in the first year:

- Formation of the Arizona Sustainable Water Consortium, which will tie the water research at UA with that at ASU, NAU, and USGS. The Consortium will, arguably, provide the world's best collection of water science and technology expertise.
- Formation of the Arizona Solar Center, which also is an attempt to draw together a number of programs in universities and industry from across the state. The focus with this Center is education, training, and outreach as well as R&D.

In both cases, the first year would be devoted to assembling the parts and creating the program plan, developing alliances and partnerships, and identifying gaps—staff and facilities—and sources of funding. An important part of both operations will be the translation of research into products, so Product Development Centers also will be considered early on, initially using existing facilities to bring universities and industry together.

FINANCIAL PLAN

Table 26 is a 10-year financial plan and investment portfolio. This plan, which is broken into three phases—year 1, years 2 to 5; and years 6 to 10—shows the major investments required to implement the seven strategies described in the previous section. Investment needs have been organized programmatically around the three areas of emphasis—organization/management; technology demonstration and commercialization; and research and development.

Key assumptions were made in putting this investment plan together:

- Investments will need to cover the entire technology life cycle, from basic research to commercialization and market penetration.
- Investment funds will continue to flow over the three phases as projected in this financial plan.
- Costs of proposed programs are based on a combination of (a) estimates provided by Arizona "champions," (b) the collective experience of Battelle's Technology Partnership Practice, and (c) benchmarking similar or related programs elsewhere.

- Sources of funds will include private financing, philanthropic funding, university endowment, federal and state government, and industry. Details on the funding mix need to be worked out for each initiative as part of the roadmap process.

Table 26: Ten-Year Funding Requirements for Sustainable Systems Prospectus (in million $)

Program Area	Year 1	Years 2 to 5	Years 6 to 10	Total Three Phases
Organization/Management				
Sustainability Czar/Sustainability Council	0.5	2.5	3.5	6.5
Policy Groups/Barrier Busting Groups	0.2	1.0	1.0	2.2
Industry Association	0.2	1.0	1.5	2.7
Image/Branding	1.0	2.0	1.0	4.0
Marketing	0.5	12.0	16.0	28.5
Workforce Development	0.3	4.0	5.0	9.3
Technology Demonstration and Commercialization				
Business Infrastructure—does not include value of the funds	2.0	8.0	10.0	20
Signature Demonstrations	50	200	1000	1,250
Product Development Centers	5	20	30	55
Eco-Industrial Parks (incremental)	10	50	100	160
Research and Development				
Research Centers	1.0	14	20	35
ZeroNet Initiative with New Mexico	0.3	4	5	9.3
Collaboratory/Technical Networks	0.3	1.0	1.5	2.8
Total Projected Funding Needs	**71.3**	**319.5**	**1,214.5**	**1,605.3**

As expected, the major expenditures are in the technology demonstration and commercialization area, with $1.25 billion proposed for signature demonstrations over the 10-year period. Key priorities among these investment items are the early demonstrations that will help establish the state's image/brand in sustainability and the disruptive technologies that will create new companies and market opportunities.

Investment Sources: While few investment sources have been confirmed at this point, it is appropriate to lay out options for financing the various activities in this Prospectus. In order of priority, they are as follows:

State funding will be required to underpin the basic organization and management of the Prospectus as it is translated into a roadmap as part of the 10-year state economic plan and then implemented. Also, the state will have to step up to cost-sharing the marketing campaign.

Private sector funding must pay for the major parts of the demonstration projects, although some federal support is possible where program and national interests intersect (e.g., healthy forests and hydrogen fuels). Banks, industry, and venture capital are all possible sources for demonstration and commercialization activities. Shared energy savings programs and third-party financing also are options, respectively, for financing

energy efficiency projects and new facilities. There is a promise of an SBIC through the RBIP, but this must be applied for during the next 6 months.

Federal funding is available, not only for support of R&D (e.g. NSF, DOE, DoD, etc.), but also for economic-development-related projects such as starting product development centers and eco-industrial parks (e.g., DOC). Special funds are available for rural and/or tribal initiatives.

Foundation funding will support a number of activities, including research, policy development, and education. There are a number of sustainability or environmentally oriented foundations in the United States, such as the Pew and Rockefeller family trusts. University foundations also need to be considered.

International bank funding also is available for international projects, e.g., those involving Mexico. The NADB is a prime example.

Commercialization returns, over the long term, will provide reinvestment possibilities for the R&D centers to augment the federal and foundation funding.

MEASURES OF SUCCESS AND PERIODIC PERFORMANCE EVALUATIONS

As these strategies and actions are implemented over the next 10 years, it will be important to assess Arizona's overall progress in meeting its sustainability goals on a regular basis.

Therefore, as a starting point, Battelle proposes three primary, high-level performance objectives be used to help the Sustainable Systems initiative measure progress made toward achieving its vision and mission.

- Arizona will establish itself as a leader in advanced water management and solar-based manufacturing and service industries and increase its employment in these sectors, doubling it by 2010.
- Arizona will establish at least two centers of excellence for sustainable systems R&D through collaborations with institutions that are major participants in existing and emerging arid lands sustainability programs, and outpace national growth rate in federal research funding in this area. One such center will evolve to "national laboratory" status by 2010.
- Arizona will establish the business climate that encourages sustainable industry growth, and institutionalize the "arid lands livability" brand by 2007 through policy and regulatory reform, broad public-private partnerships, and aggressive outreach and communications.

The strategies contribute to the success measures, as shown in Table 27.

Table 27: Contribution of Seven Strategies to the Proposed Success Measures (H=high; M=medium)

Success Measure	Strategy One	Strategy Two	Strategy Three	Strategy Four	Strategy Five	Strategy Six	Strategy Seven
Establish leadership in water and solar industry sectors and double employment by 2010	H	H	M	M			H
Develop at least two Centers of Excellence; one evolves to national laboratory status by 2010	H	H				H	M
Establish the business climate for sustainable systems industry to flourish and the Arizona brand by 2007	H	H	H	H	H		M

Further, Battelle recommends that each objective be broken into "deliverables," which can show progress annually.

Arizona should institute a process of periodically measuring its performance in achieving these objectives. One approach could be to prepare a "State of Arizona Sustainability Report," as described previously within Strategy Four, with emphasis on progress made toward the success factors listed above. This would allow the dual opportunity to focus on achievements made in the sustainable development of Arizona in general as well as achievements made in pursuing economic benefits through sustainable systems.

Summary

The Sustainable Systems Prospectus represents a unique vehicle and mechanism to propel Arizona into a leadership position in sustainable development, which will develop the markets and infrastructure to encourage a new manufacturing industry to grow, create job opportunities, and provide an attractive place to live and raise a family.

The basic elements for Arizona's sustainable economy exist today. They include universities with active research programs that can serve as the engine for new technologies and products; a receptive industry that can be the first market for such products and services; state, tribal, and local governments that are concerned about water, energy, land, forests, and the environment and are willing to do something about them; NGOs that are engaged in establishing workable policies to balance economic and population growth with protection of the environment for future generations; and favorable climate and geographic factors.

The purpose of this Prospectus, as much as anything, was to pull all these parts together into one place, so that the huge asset base can be reviewed by all the stakeholders and then appropriately leveraged into economic development. It will take a sustained partnership between governments, industry, NGOs, and universities to achieve the development of the "*arid lands livability*" label for Arizona and the associated economic growth. New research innovations must continue as current innovations are tested and qualified in signature demonstrations; and new policies, regulations, and incentives must be developed to create the business-friendly environment that is so important for new industry creation.

Some might argue that the *"arid lands livability"* label or brand is too confining (or even negative), but it is important for Arizona to clearly differentiate itself from other states and regions that have established sustainable systems industries. The state's unique position of having major urban growth, as well as rural area development occurring in land that is arid or semiarid, provides the opportunity for the "branding" that will enable huge exports, given that more than a third of the developable land in the world is in this same condition.

All this effort takes people and money. Arizona has the thought leaders in government, the private sector, and the NGOs, to accomplish this successfully. This leadership must come together now to convince outside investors that this program is worth the investment. And, state government, both the Governor and the legislature, must be committed for this 10-year journey, be willing to remove barriers, and offer encouragement and incentives.

This Prospectus lays out the public and private investments that can make Arizona a leader in this next technology wave—a sustainable world. To embark on this road is probably the single most important decision for Arizona at this time. It is Arizona's opportunity to lose!